

***Water Quality Improvement Plan  
for***

**Milford Creek  
Dickinson County, Iowa**

Total Maximum Daily Load  
for Phosphorus



Iowa Department of Natural  
Resources  
Watershed Improvement Section  
2007



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## **General Report Summary**



Milford Creek in Dickinson County (photo taken by IDNR in 2005).

### **What is the purpose of this report?**

This report serves dual purposes. First, it provides local watershed managers and citizens with a resource for understanding and fixing the problems in Milford Creek. Second, it satisfies the Federal Clean Water Act requirement to develop a Total Maximum Daily Load (TMDL) for Milford Creek, a.k.a. Mill Creek, which is listed on the state's 2004 Impaired Waters list (303(d) List).

### **What's wrong with Milford Creek?**

Excessive amounts of algae in the stream are causing violations of the state's water quality standards for dissolved oxygen. Too much algal growth results in low nighttime levels of dissolved oxygen in the stream, as well as extreme fluctuations in oxygen levels that stress the aquatic life. This has resulted in a chronic impairment to the stream's fish and invertebrate communities.

### **What is causing the problem?**

The excessive algal growth in Milford Creek is caused by a combination of physical factors and the overabundance of plant nutrients, specifically phosphorus. Phosphorus contributes to oxygen consumption indirectly by causing excessive plant growth in the stream, especially under low flow conditions and warm temperatures. This leads to extreme levels of nighttime respiration by algae and decomposition of dead plants, both of which deplete oxygen levels in the stream.

### **What can be done to improve Milford Creek?**

To improve dissolved oxygen levels and restore aquatic health in Milford Creek, phosphorus loading to the stream needs to be reduced significantly and the stream physical conditions need to be improved. Reducing phosphorus inputs from point and nonpoint sources will help limit algae growth during late summer critical conditions. Reducing stream temperature and light availability will also limit algal growth. Phosphorus removal in wastewater treatment, reductions in urban and agricultural stormwater runoff, and the lowering of lake nutrient concentrations in Lower Gar Lake and the upper Iowa Great Lakes will all help improve water quality in Milford Creek.

### **Who is responsible for a cleaner Milford Creek?**

The water quality in Milford Creek is a shared responsibility and improving it must be considered a cooperative effort. Government and wastewater treatment facilities will be responsible for adjusting effluent limits from point sources, while nonpoint sources can be influenced by everyone living or working in the watershed. Landowners, tenants, businesses, and citizens alike have the ability to improve management practices in the watershed and educate others about why Milford Creek needs their help.



Algae and organic materials (shown in picture) consume oxygen in Milford Creek through respiration and decay (photo taken by IDNR, 2005).

## Technical Elements of the TMDL

<b>Name and geographic location of the impaired waterbody for which the TMDL is being established:</b>	<b>Milford Creek, S11, T98N, R37W, near the City of Milford in Dickinson County, Iowa</b>
Waterbody ID and location of impaired segments:	IA 06-LSR-0300 (from mouth to confluence with unnamed tributary)  IA 06-LSR-0305 (from confluence with unnamed tributary to outlet structure at Lower Gar Lake)
Existing stream classification:	IA 06-LSR-0300: A1 and B(WW-2) (Primary contact recreation and Type 2 warm water aquatic life)  IA 06-LSR-0305: A1 and B(WW-1) (Primary contact recreation and Type 1 warm water aquatic life) <sup>†</sup>
Impaired beneficial uses:	Aquatic life uses (Class B)
TMDL priority level:	Consent Decree waterbody (High)
Identification of the pollutant and applicable water quality standards:	Phosphorus is indirectly causing violations of the state's numeric dissolved oxygen criteria through excessive algae respiration & decomposition. For Class B(WW-2) streams, the minimum dissolved oxygen concentration is 5 mg/l for at least 16 hours per day and an absolute minimum of 4 mg/l. For Class B(WW-1) streams, the minimum dissolved oxygen level is 5 mg/l at all times.

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<sup>†</sup> Dependent on EPA approval of revised water quality standards (March 22, 2006) and final UAA rulemaking.

Quantification of the pollutant load that may be present in the waterbody and still allow attainment and maintenance of water quality standards:	The maximum amount of total phosphorus that Milford Creek can tolerate under critical environmental conditions is 7.0 lbs per day. Critical environmental conditions refer to periods of low streamflow and high temperatures, when conditions are most stressful for aquatic life. Load capacities for additional flow conditions are provided in the report.
Quantification of the amount the current pollutant load in the waterbody deviates from the pollutant load needed to attain and maintain water quality standards:	Current phosphorus loading to Milford Creek during critical conditions is commonly as high as 91.8 lbs/day. This exceeds the tolerable level by over 92%.
Identification of pollution source categories:	Both point and nonpoint sources of phosphorus contribute to the impairment in Milford Creek. Point sources in the watershed include the Iowa Great Lakes Sanitary District WWTP and one permitted open feedlot. Nonpoint sources include urban and agricultural areas, atmospheric deposition, and outflows from Lower Gar Lake and the upper Iowa Great Lakes watershed.
Wasteload allocations for pollutants from point sources:	Under critical environmental conditions, the wasteload allocation for point source wastewater is 6.9 lbs/day total phosphorus. The wasteload allocation for the permitted open feedlot is zero, as animal feeding operations are not allowed to discharge to surface waters. Wasteload allocations for additional flow conditions are provided in the report.
Load allocations for pollutants from nonpoint sources:	Under critical environmental conditions, the load allocation for nonpoint sources is 0.1 lbs/day, which includes background loading from atmospheric deposition. Load allocations for additional flow conditions are provided in the report.
A margin of safety:	A margin of safety is implicit in conservative assumptions used to define the maximum loading capacity.

Consideration of seasonal variation:	The maximum loading capacity was designed to allow the stream to meet water quality standards under critical environmental conditions, during seasonal low flows and high temperatures.
Reasonable assurance that load allocations and wasteload allocations will be met:	The issuance of a NPDES permit for the IGLSD, existence of an approved TMDL for Lower Gar Lake, and the availability of technical and financial assistance grants for local watershed improvements in Milford Creek provide reasonable assurance that load reductions can be met.
Allowance for reasonably foreseeable increases in pollutant loads:	No allowance for a future increase in pollutant loading was provided. A new wastewater treatment facility and recent efforts in the Iowa Great Lakes watershed to foster innovative stormwater management through low impact development and citizen education indicate that an increase in pollutant loading is not likely.
<b>Implementation plan:</b>	<b>Although not required by the Clean Water Act, an implementation plan is included in Chapter 4 of this report.</b>

## **1. Introduction & Summary**

The Federal Clean Water Act requires that all states develop lists of impaired waters which are not meeting designated water quality standards. This list is commonly called the 303(d) list. For each impaired waterbody that appears on the list, a total maximum daily load (TMDL) report must be developed.

A TMDL is a calculation of the maximum amount of pollution a waterbody can tolerate without exceeding its water quality standards. The report must allocate portions of the load capacity to both nonpoint and point sources (called the load allocation and wasteload allocation, respectively), allow for a margin of safety, and account for seasonal variations and critical environmental conditions.

This document is the TMDL report for Milford Creek, a.k.a. Mill Creek, located in Dickinson County, Iowa. Milford Creek has been identified as not fully supporting its Class B aquatic life uses due to poor biological health and violations of the state's numeric dissolved oxygen criteria. A Stressor Identification (SI) for the stream has determined that excessive algae and macrophyte growth, encouraged by an overabundance of plant nutrients, are the primary causes of the impairment. This TMDL specifically addresses phosphorus as the primary factor controlling algal growth in the stream.

Milford Creek was included in a 2001 lawsuit brought forth against the U.S. Environmental Protection Agency regarding the status of Iowa's TMDL program. The outcome of this lawsuit was a formal Consent Decree which specified that TMDLs be developed for all impaired waters on the 1998 303(d) list by December 15, 2009, which includes Milford Creek.

In addition to satisfying legal requirements to develop a TMDL for Milford Creek, the purpose of this report is to provide a resource to help guide future improvements in the Milford Creek watershed. Restoring the water quality in Milford Creek will depend upon the cooperation and combined efforts of local citizens, landowners, stream managers, and government agencies alike. This report can help those groups by identifying appropriate load reduction targets, pollutant sources, and management alternatives.

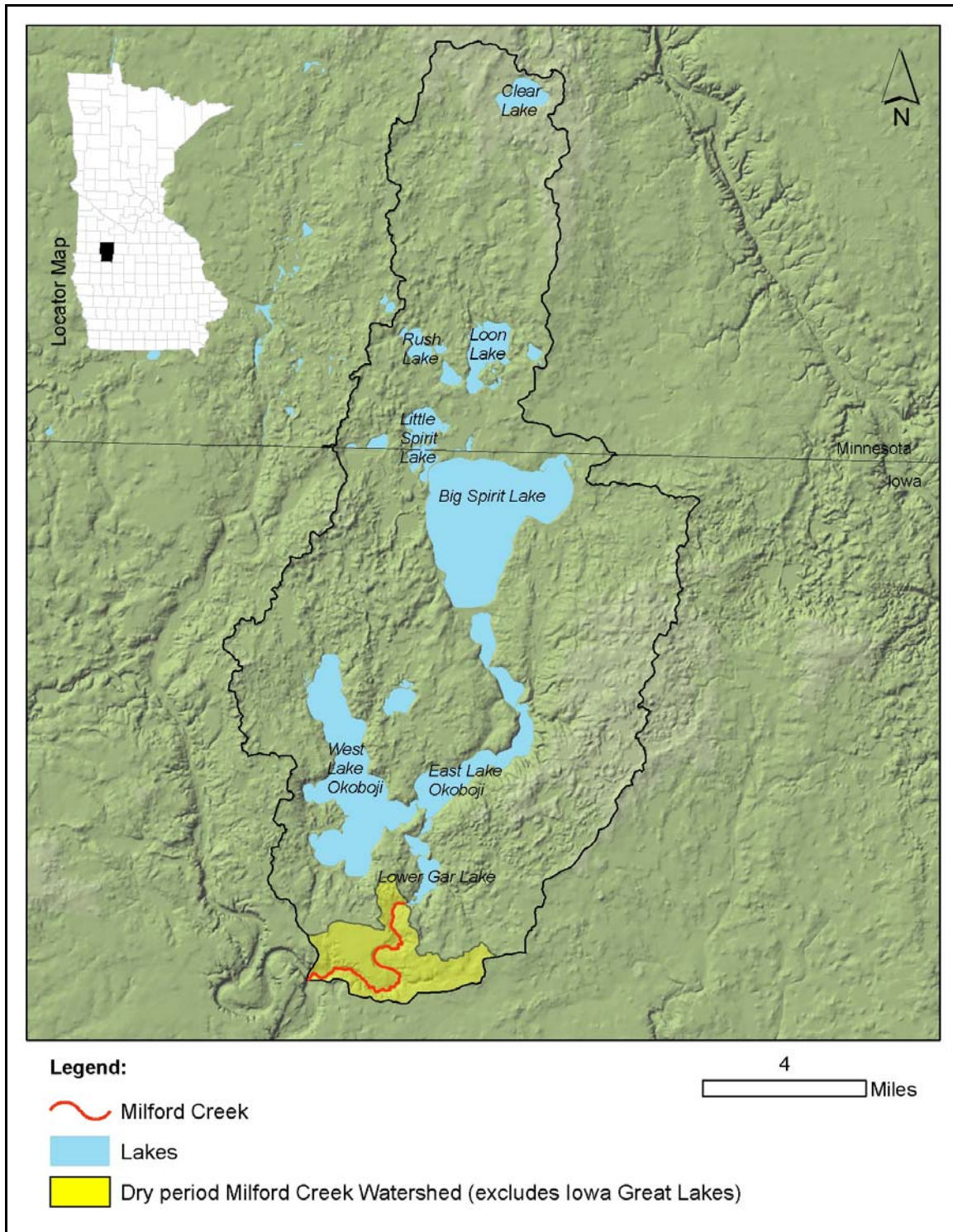


Figure 1. The Milford Creek watershed.

## **2. Description and History of Milford Creek**

Milford Creek is a stream located in central Dickinson County, Iowa. The creek begins at the outlet structure of Lower Gar Lake and flows south and west for 6.2 miles until it reaches the Little Sioux River.

### **2.1. Milford Creek**

*Hydrology.* Milford Creek is a relatively short, wide, and shallow stream. For 305(b) assessment purposes, the stream is split into two segments: Waterbody ID# IA 06-LSR-0305 (upstream) and Waterbody ID# IA 06-LSR-0300 (downstream) (Figure 2). The upstream segment (2.9 miles long) is rather lake-like, being wide, shallow, and slow-moving. A small drainage ditch which enters the stream just north of the city of Milford is the only defined surface water inflow to this segment.

The downstream segment (3.3 miles long) is more stream-like, with a faster and more steady current. A small intermittent tributary enters Milford Creek approximately halfway between the headwaters and mouth, marking the divide of the stream's two segments.

Milford Creek is an altered stream system. Under natural conditions, the creek drains Lower Gar Lake and serves as the outlet for the entire chain of the Iowa Great Lakes. Water from Upper Gar, Minnewashta, East and West Okoboji, Big Spirit, and other lakes drains through Milford Creek en route to the Little Sioux River. However, a low-head control structure separates Lower Gar Lake from Milford Creek (Figure 3), and during extended dry weather, outflows from the lake may cease for months to years at a time (Figure 4) (Stenback and Crumpton, 2006).

During dry periods, streamflow in Milford Creek is sustained primarily by discharges from the Iowa Great Lakes Sanitary District (IGLSD) wastewater treatment plant (WWTP), which is located near the head of Milford Creek just below the Lower Gar Lake dam. At times, wastewater effluent can contribute over 90% of the flow to Milford Creek. Between May 26<sup>th</sup> and August 31<sup>st</sup> in 2004, wastewater effluent provided an average of 62% of the total flow detected six miles downstream (Figure 5).

Due to the consistency of wastewater discharges, base flow (flow not affected by surface runoff) in Milford Creek is stable at 2 cubic feet per second (cfs) or more throughout the summer; however, when wastewater effluent dominates streamflow, the stream can have a pronounced daily flow cycle (Figure 6). Daytime flows are higher (4-5 cfs) as municipal water users consume water, while overnight flows often drop below 3 cfs as residential water use declines.

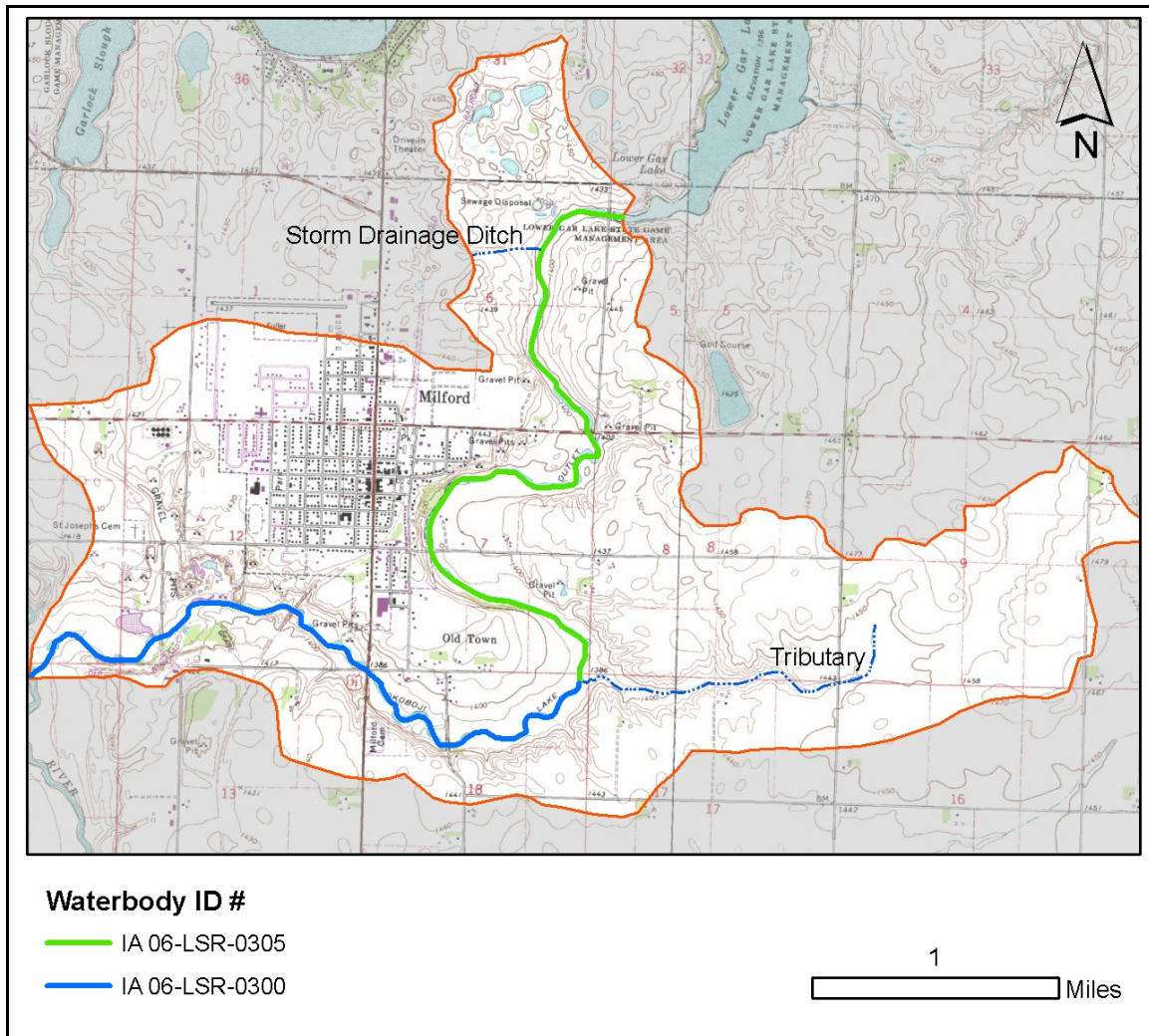


Figure 2. Segmentation of Milford Creek for Clean Water Act reporting purposes.



Figure 3. Low head dam separating Lower Gar Lake from Milford Creek (image from IDNR Use Attainability Analysis 2006).

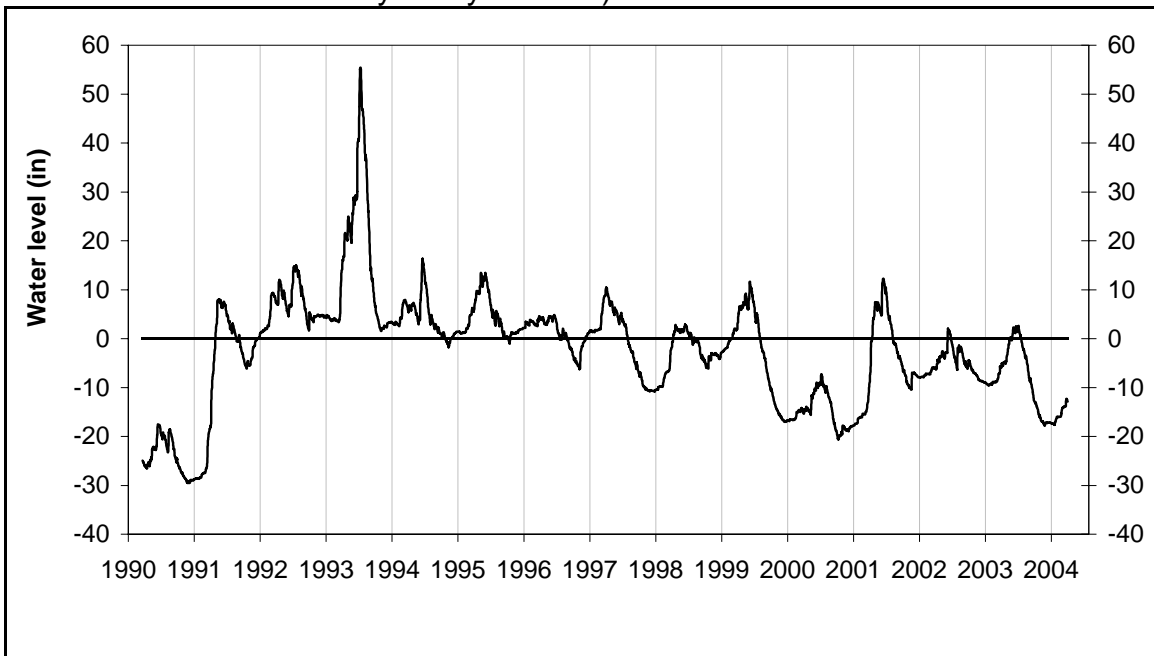


Figure 4. Water levels in West Lake Okoboiji collected by IDNR. When gage height exceeds zero, water flows from Lower Gar Lake into Milford Creek.

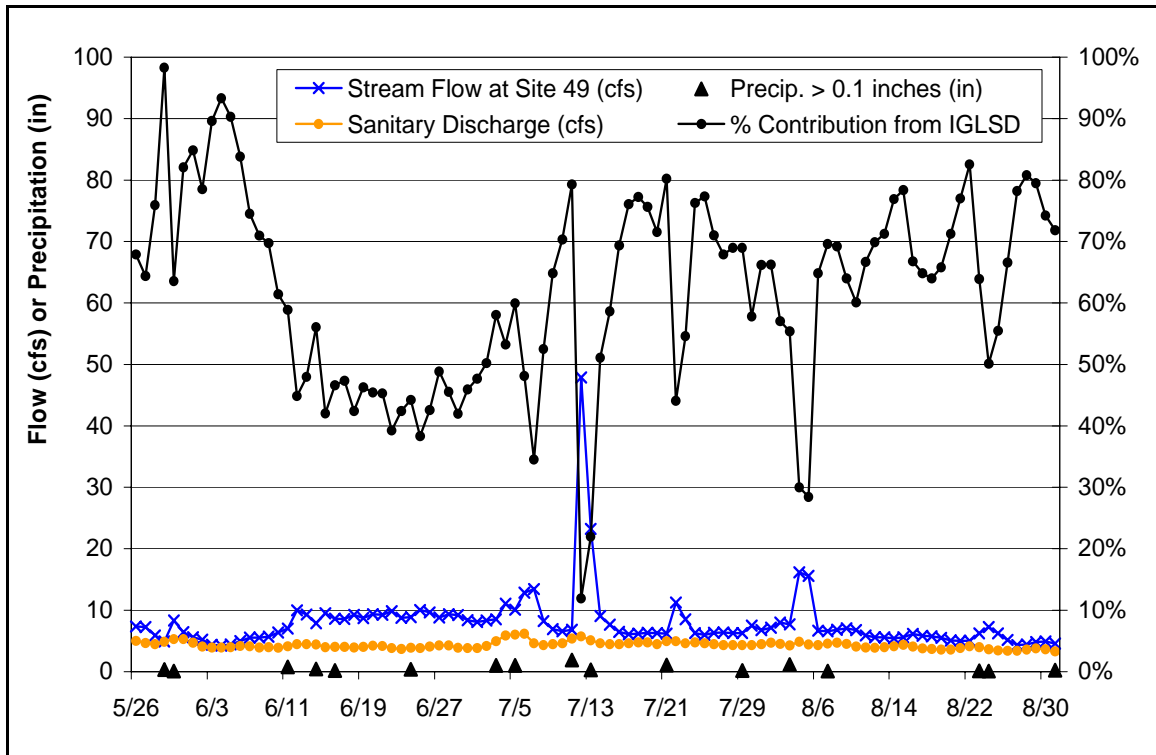


Figure 5. Flow contribution of the IGLSD to Milford Creek in summer 2004.

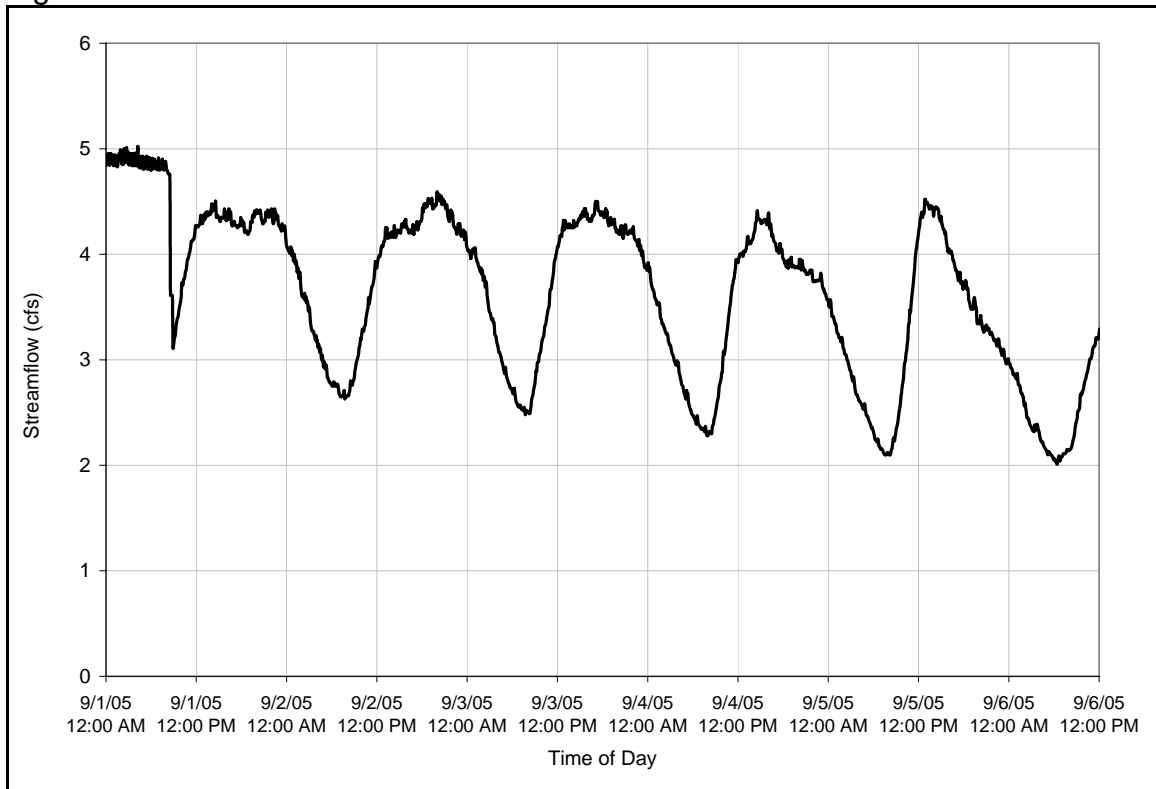


Figure 6. Continuous streamflow record from Milford Creek from 9/1/2005-9/6/2005 (Site #4). The cyclical pattern results from wastewater influence in the stream.

## 2.2. The Milford Creek Watershed

Milford Creek has a total watershed area of approximately 93,766 acres, shown previously in Figure 1. During dry periods, when no water is received from Lower Gar Lake, the catchment area draining directly to the stream is reduced to approximately 4,065 acres, depicted (Figures 1 and 2).

*Land Use.* Land use in the watershed is predominantly agricultural, with the most common crops being corn, soybeans, and hay (Table 1). Pasture and livestock production, primarily corn and hogs, are also prevalent. There is one permitted animal feeding operation (AFO) in the immediate drainage area, located near the mouth of Milford Creek.

Urban development and expansion are also prevalent in this region, due to the economic and recreational attraction provided by the Iowa Great Lakes. Human populations in the watershed vary greatly by season, due to demographic patterns and tourism.

**Table 1. 2002 Land use in Milford Creek watershed (IDNR, 2004).**

Land use	Entire IGL watershed		Area draining directly to Milford Creek (excluding IGL)	
	Acres	Pct.	Acres	Pct.
Row crop	45,945	49%	1,478	36%
Pasture	4,688	5%	803	20%
Grass	12,190	13%	732	18%
Urban/Developed	3,751	4%	568	14%
CRP	5,626	6%	294	7%
Timber	3,751	4%	87	2%
Hay	938	1%	81	2%
Water/Wetland	16,878	18%	22	1%
Total	93,766	100%	4,065	100%

*Soils, climate, and topography.* The watershed ranges from nearly level to strongly sloping (0-14%), with prairie-derived soils developed from Wisconsin till, loamy and sandy glacial outwash, and alluvium. The most common soil types in the watershed are Clarion and Nicollet on the uplands, and Wadena, Estherville, and Coland on the outwash plains and stream valleys. Average annual precipitation is 28.3 inches.

## 2.3. Biological Impairment

*Problem statement.* Milford Creek is biologically impaired, which means it is not fully supporting the aquatic life that should be present in the stream. Since 1994, the Class B (aquatic life) designated uses in Milford Creek have been assessed by the Iowa Department of Natural Resources (IDNR) as either “partially supported” or “not supported” for 305(b) purposes. The original assessment was based on a 1990 survey showing low habitat diversity and fish populations in the stream. A stream use

assessment done later in October of 1995 found that the fish community lacked several of the expected species/genera for Class B(LR) streams in the same ecoregion. In 2001, biological and chemical monitoring was done in support of TMDL development at two sites on Milford Creek (shown in Figure 7). Results of this monitoring documented the stream's chronically impacted biological community as well as water chemistry problems ("extremely high levels of total phosphorus...and potential problems with organic enrichment"). Since then, Milford Creek has remained on Iowa's impaired waters list for each successive 305(b) cycle.

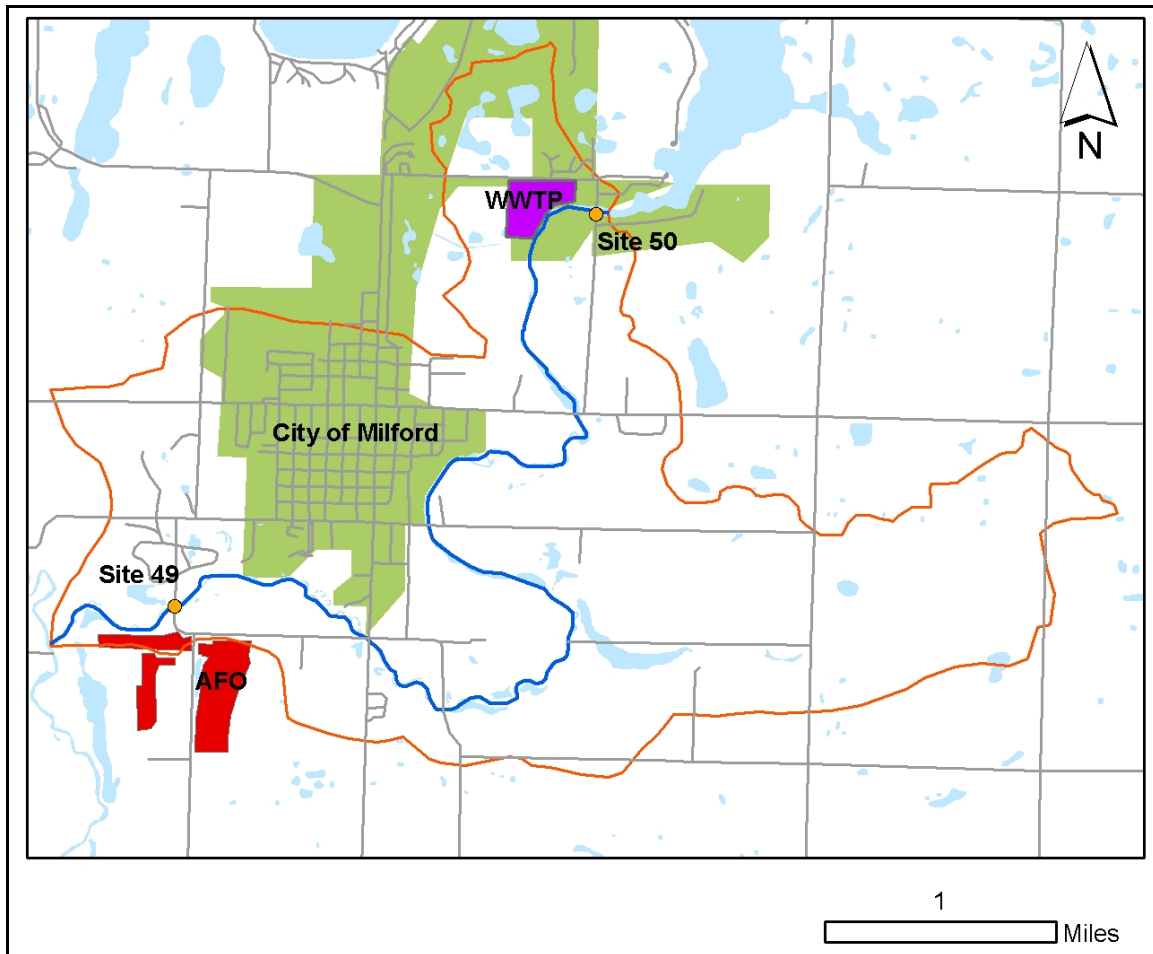


Figure 7. 2001 monitoring sites in Milford Creek.

*Bioassessments and the Index of Biotic Integrity (IBI).* Stream biological assessments incorporate benthic macroinvertebrate sampling, fish sampling, and habitat descriptions to identify and quantify aquatic life impairments in warmwater streams. Biological data are summarized numerically into a Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) and a Fish Index of Biotic Integrity (FIBI). The FIBI and BMIBI combine several quantitative metrics to provide a broad assessment of the stream on a scale from 0 to 100. A report on the Iowa bioassessment monitoring program is available online at [www.iowadnr.gov](http://www.iowadnr.gov) (Wilton, 2004).

Table 2 shows the FIBI and BMIBI scores measured in Milford Creek in 2001 and the Biological Impairment Criteria (BIC) used to determine aquatic life use impairments in Class B streams in Iowa. The BIC are determined using a reference stream approach, in which the 25<sup>th</sup> percentile of data collected at stream ecoregion reference sites from 1994-2004 serves as the impairment criterion. In Milford Creek, the average BMIBI score of 29 is well below the BIC of 62, while FIBI scores rank better: the FIBI score at the downstream (riffle) site is slightly below the BIC, while the upstream (non-riffle) site exceeds the BIC, probably due to the influence of Lower Gar Lake on Milford Creek during high flow periods.

The IBI results for the upstream segment of Milford Creek have a low degree of confidence. That segment's original designation as a general use stream means that comparatively, it is a smaller and simply different system than the Class B Wadeable streams for which the reference BIC were developed. Also, its status as a hydrologically-altered system (due to the dam at Lower Gar Lake) further complicates the ability of comparing reference stream scores to those in upper Milford Creek. For these reasons, the upstream segment's Class B use was considered "partially supported" in the most recent 305(b) assessment (as opposed to "not supporting"), indicating a lower degree of confidence associated with the assessment.

However, IBI scores in the downstream segment of Milford Creek do effectively characterize the stream's biological impairment. This segment compares well to the waterbodies used to develop reference stream BIC, and the low BMIBI and FIBI scores adequately reflect the stream's biological condition. Thus, the lower segment was given a "not supporting" assessment of Class B uses in the most recent 305(b) assessment to indicate a higher degree of confidence.

**Table 2. 2001 FIBI and BMIBI scores in Milford Creek compared to Des Moines Lobe (Ecoregion 47(b)) reference conditions.**

Index	Site 50 (upstream)	Site 49 (downstream)	Ecoregion 47(b) Biological Impairment Criteria
BMIBI	14	44	62
FIBI (riffle)	Not applicable	50	53
FIBI (non-riffle)	38	Not applicable	32

*Stressor Identification.* In order to determine the cause of the biological impairment in Milford Creek, the DNR followed the protocol outlined in the EPA Stressor Identification Guidance document (USEPA, 2000). The Stressor Identification (SI) is a process used to relate biological impairments to one or more specific causal agents and to separate water quality impacts from habitat impacts. The full SI document is included in the appendix of this report (IDNR, 2004b).

On page 13 of the Milford Creek SI, it is stated:

*“Milford Creek is primarily impaired by degraded water quality and secondarily by habitat alterations. The main water quality problem is nutrient enrichment which is allowing excessive growth of plants and algae which are depleting dissolved oxygen supplies at night. Flow alteration and silt/sediment deposition also contribute to the biological impairment.*

*For the purposes of TMDL development, the cause of impairment is low dissolved oxygen and excess aquatic plant and algal growth caused by excess nutrients and high BOD.”*

Physical observations of Milford Creek lend support to the notion that excessive macrophyte and algal growth exist in the stream, as documented by many photos (shown previously and in Appendix E). This abundant algae and plant growth leads to the extreme fluctuations of dissolved oxygen in the stream from daytime to nighttime, which is recorded using continuously operating data loggers. Data from one of these samplers is shown in Figure 8. Such drastic changes in stream oxygen levels stress aquatic life, and the nighttime lows are sufficient to violate state water quality standards and cause fish kills such as the two shown in Appendix D.

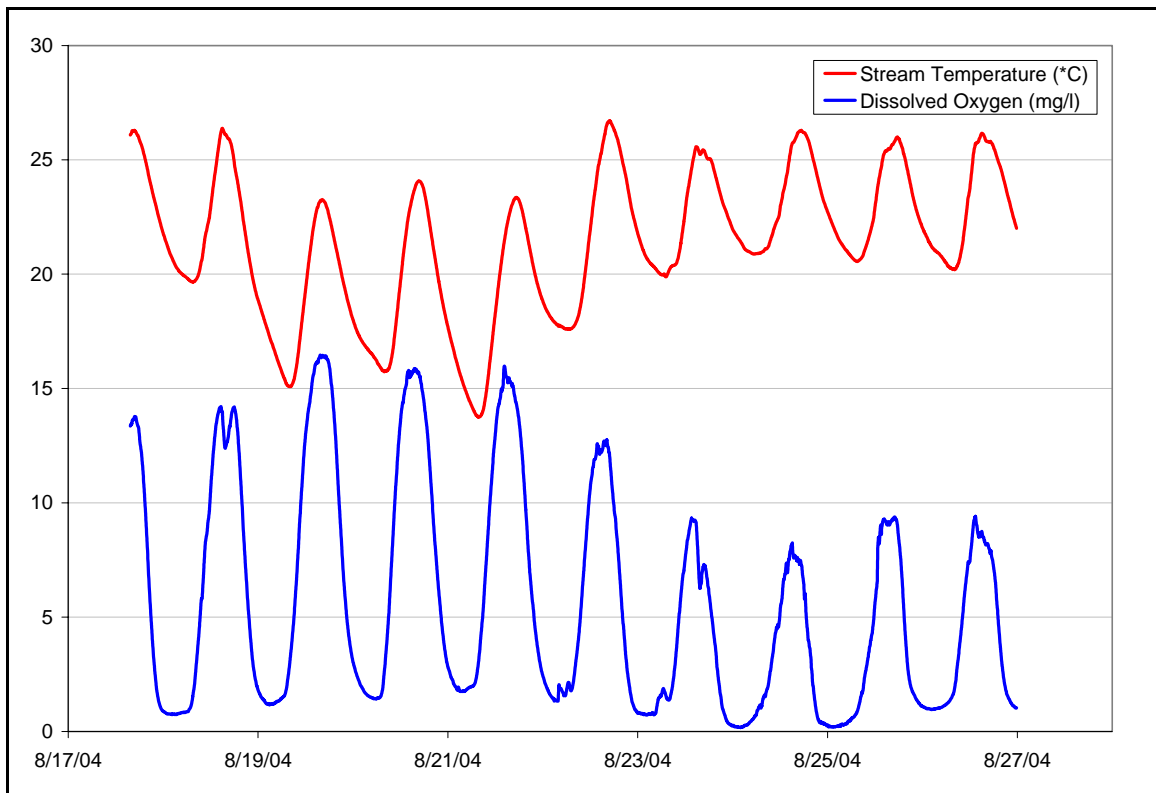


Figure 8. Continuous autosampler data collected at Site #49 during low streamflow period (no flow over Lower Gar dam).

The excessive plant and algal growth in Milford Creek can be attributed to a combination of nutrient enrichment and physical water conditions. During wet/cool periods, or when flow is being received from Lower Gar Lake, dissolved oxygen levels in Milford Creek

may be generally sufficient to the support aquatic life uses (Figure 9). However, hot and dry periods provide ideal conditions for abundant plant & algae growth and the extreme dissolved oxygen fluctuations seen in Figure 8.

To define the critical nutrient targets for Milford Creek, the Qual2K stream model was used to establish a mechanistic linkage between nutrients in the stream, algal growth, and dissolved oxygen levels. Based on this modeling, phosphorus was determined to be the primary limiting nutrient which controls algae growth in Milford Creek---reductions in nitrate+nitrite and ammonia did not significantly affect stream dissolved oxygen levels under critical environmental conditions. Therefore, this TMDL focuses on lowering phosphorus levels in the stream to control the excessive algae, improve dissolved oxygen levels (to comply with water quality standards), and increase biotic integrity index scores.

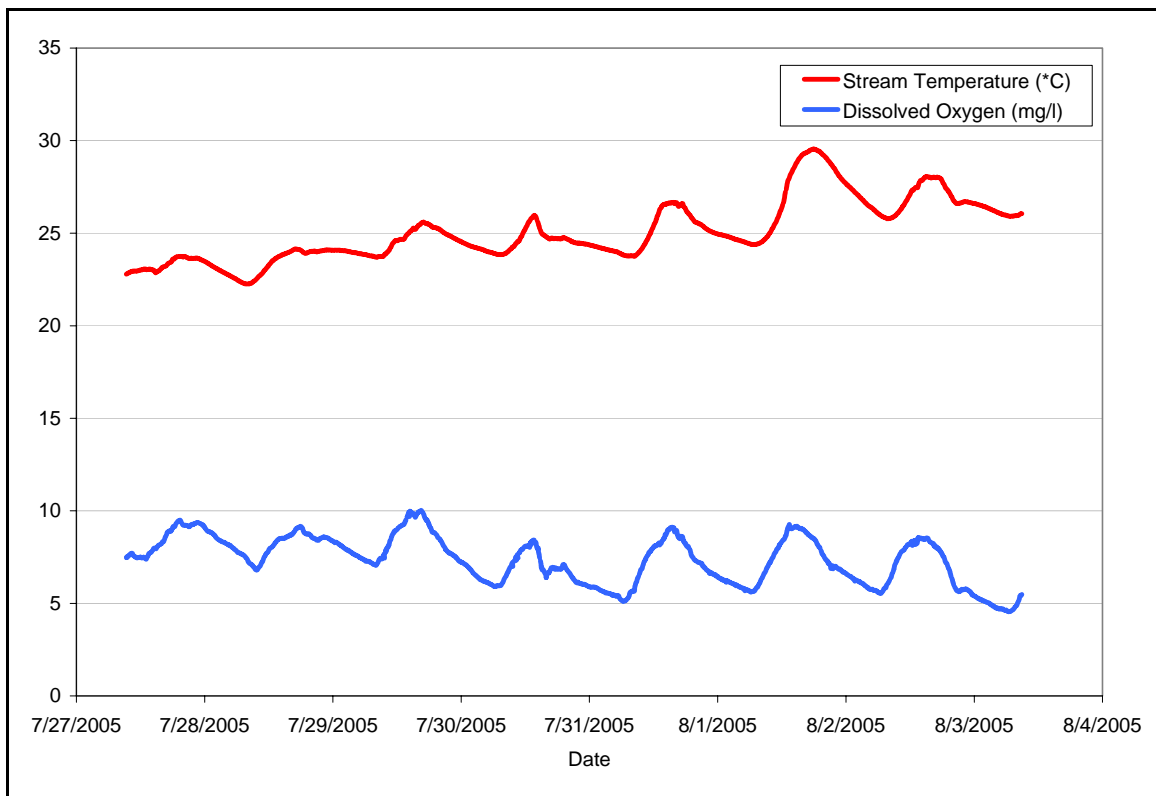


Figure 9. Continuous autosampler data collected at Site #50 during high streamflow period (flow over Lower Gar dam).

### 3. Total Maximum Daily Load (TMDL) for Phosphorus

A Total Maximum Daily Load (TMDL) is required for Milford Creek by the Federal Clean Water Act. This chapter will quantify the maximum amount of phosphorous that Milford Creek can tolerate in order to meet the state's water quality standards for dissolved oxygen.

#### 3.1. Problem Identification

*Applicable water quality standards.* The State of Iowa does not have numeric criteria for phosphorus in streams or lakes. Rather, state water quality standards protect aquatic life in all Class B streams by giving numeric dissolved oxygen criteria. Currently, the designated uses for Milford Creek are Class B(WW-1) in the upstream segment and Class B(WW-2) in the downstream segment (IAC, 2006). The upstream segment's use designations are tentative based on a recent Use Attainability Analysis (UAA) performed on the stream which calls for the aquatic life use to be downgraded from a Class B(WW-1) to Class B(WW-2).

For Class B(WW-2) streams, Iowa water quality standards state that dissolved oxygen must be no less than 5.0 mg/l dissolved oxygen for at least 16 hours out of every 24-hour period, and never less than 4.0 mg/l dissolved oxygen. Should the upstream segment of Milford Creek remain designated for Class B(WW-1) uses (contrary to the UAA recommendation), state water quality standards would call for dissolved oxygen to be no less than 5.0 mg/l at all times in that segment.

*Data sources.* Biological assessment data was collected at two sites (#49 and #50) in 2001. Water chemistry data was collected monthly at the same two sites from March through November of 2001. Additional samples were collected in May and June of 2002 at Site 50 and June through August at Site 49 in 2004. In 2005, at the request of local stakeholders, an additional round of monitoring was conducted in the stream to better understand and characterize the pollutant sources. This included adding five new water chemistry monitoring sites (Figure 10), automatic samplers to measure continuous dissolved oxygen, temperature, and flow, and a time-of-travel study using tracer dyes.

Point source effluent data was provided by the Iowa Great Lakes Sanitary District wastewater treatment facility. This data included average and maximum daily flows (1998-present), hourly flows from 8/29/05-9/15/05, monthly discharge monitoring reports for CBOD5, ammonia nitrogen, pH, temperature, toxicity, total suspended solids (1991-present), and weekly effluent total and dissolved phosphorus concentrations from 2/23/05 to 6/20/06.

To quantify pollutant loading from Lower Gar Lake and the rest of the Iowa Great Lakes to Milford Creek, information from a 2006 Iowa State University study was utilized (Stenback and Crumpton, 2006). This study established a mass-balance budget for water and total phosphorus in the Iowa Great Lakes system, which included estimating exports

to Milford Creek during the years 1999-2005. A supplemental study was also performed to estimate long term loadings from the IGLSD WWTP (summary in Appendix E).

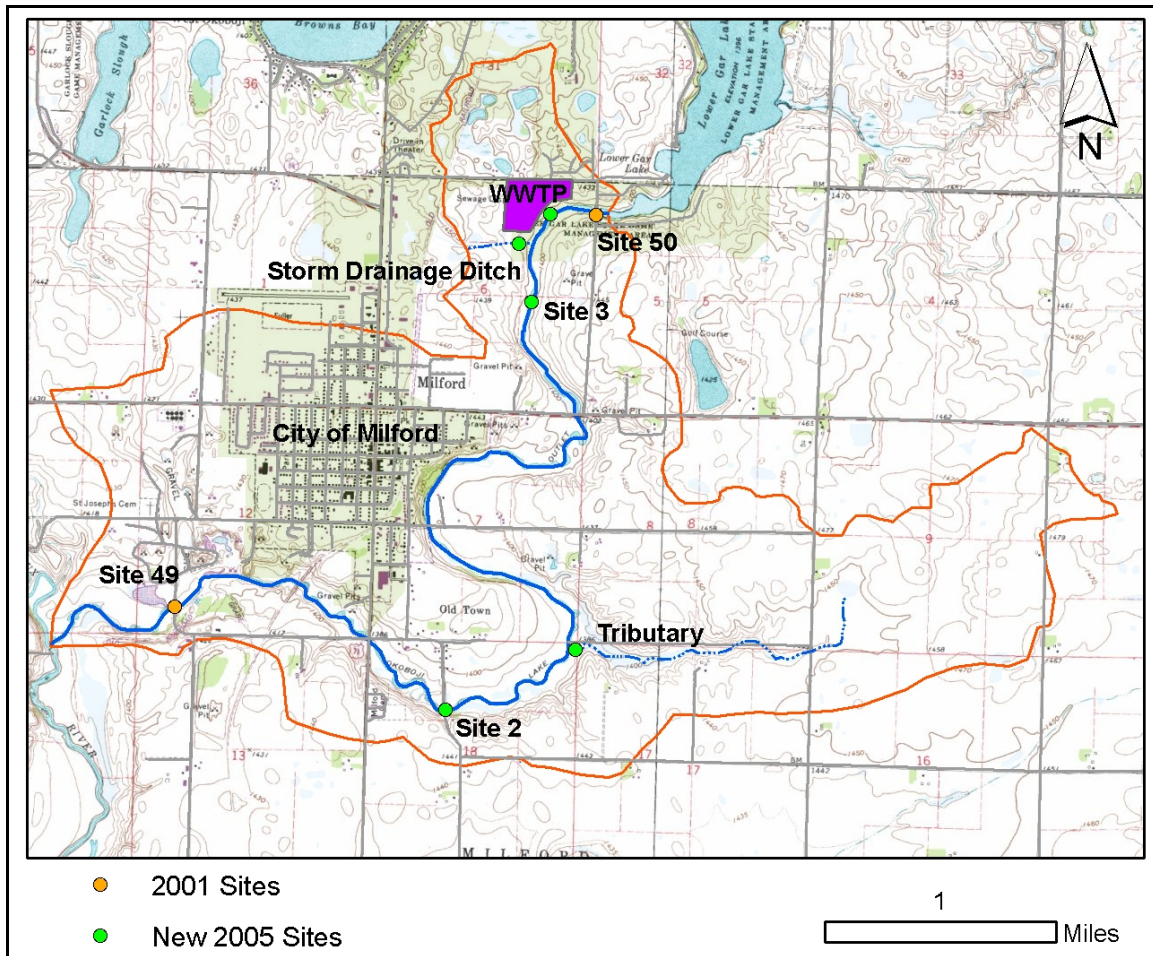


Figure 10. Location of 2005 monitoring sites in Milford Creek.

*Interpreting Milford Creek data.* Total phosphorus concentrations in Milford Creek are unusually high. The maximum concentration measured in the stream occurred on August 30, 2005 (Site 3) and was 3.6 mg/l or 3600 µg/l. The median total phosphorus concentration during 2001-2005 sampling was 1.1 mg/l or 1100 µg/l. For comparison, the United States EPA recommends a maximum concentration of 0.118 mg/l or 118 µg/l total phosphorus in the Western Corn Belt Plains Ecoregion and 0.076 mg/l or 76 µg/l in the Corn Belt and Northern Great Plains Ecoregion to control nuisance algae growth in streams and rivers (USEPA, 2000).

In general, phosphorus levels are lower at the upstream site and higher at the downstream site. Figure 11 shows the boxplots for all total phosphorus data measured at four locations along the stream from 2001-2005, moving from upstream (Site 50) to downstream (Site 49). Between Sites 50 and 3, two sources of flow enter the stream: the IGLSD wastewater treatment plant and a small rural drainage ditch. Wastewater inputs, high in phosphorus content, cause a significant increase in downstream water column

concentrations. This is also evident in Figure 12 which shows concentrations measured at four different sites on the same day for different sampling periods.

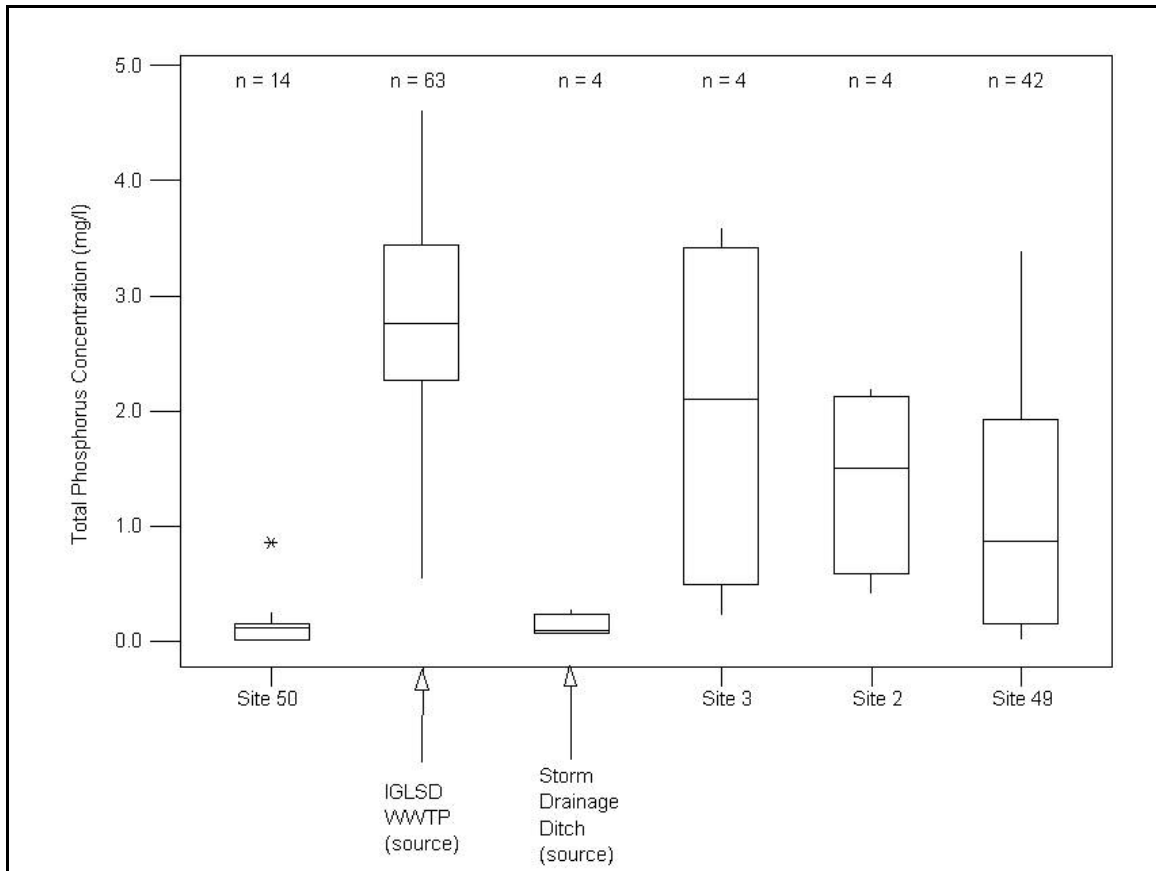


Figure 11. Total phosphorus boxplots from upstream (left) to downstream (right), including data collected at two surface water inflows.

Temporally, total phosphorus concentrations are highest in the stream in late summer and early fall, when the stream is dominated by wastewater. This contrasts with many streams and rivers in Iowa where nutrient loading is driven primarily by nonpoint source runoff. Figure 13 shows the monthly total phosphorus boxplots in Milford Creek.

Measured levels of chlorophyll indicate high plant and algal growth in Milford Creek. In August 2004 at site 49, chlorophyll a concentrations were 72  $\mu\text{g/l}$  in the water column, 130  $\mu\text{g/cm}^2$  in the periphyton, and 38  $\mu\text{g/cm}^2$  in the sediment. Observations and photos taken of the stream also document high levels of aquatic plant growth and are included in Appendix D.

Dissolved oxygen measurements taken over several two-week periods using automatic samplers show that oxygen levels fluctuate widely over each 24-hour period, with nighttime concentrations often dipping below 2 mg/l for four to twelve hours at a time. During low flow/late summer periods, these violations occurs throughout the length of the stream and is documented at all monitoring sites.

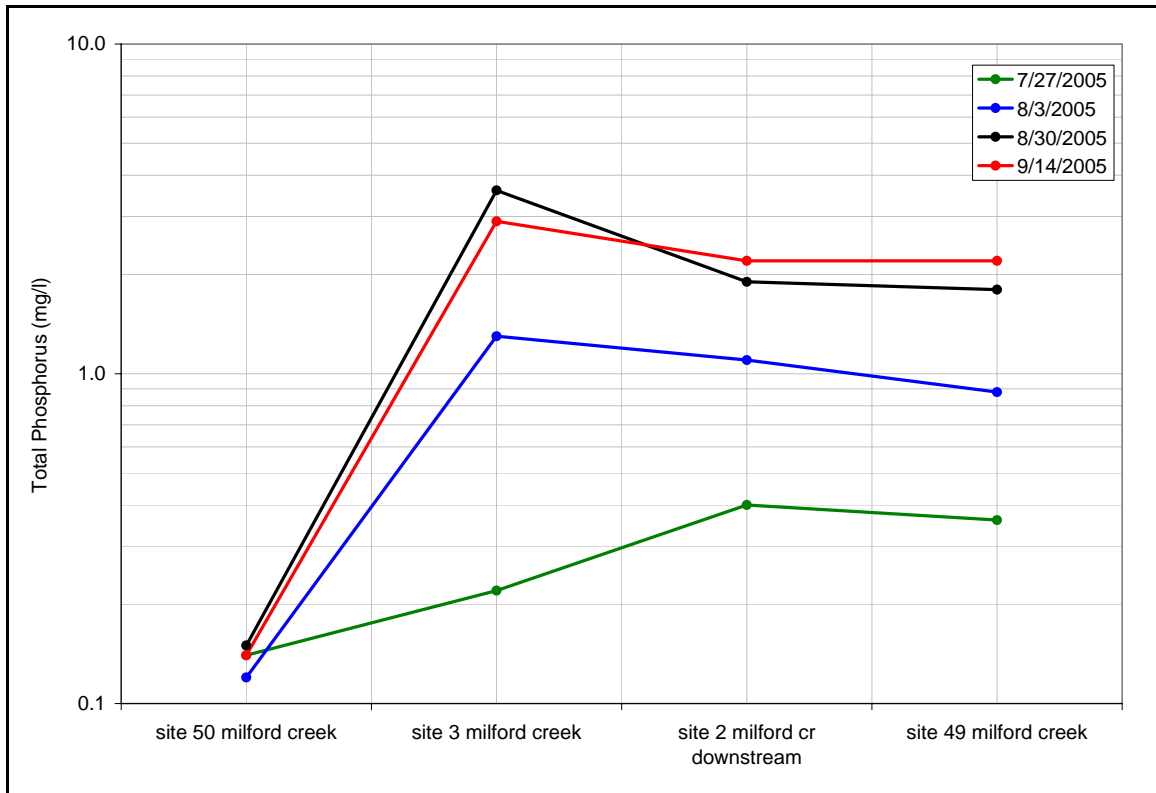


Figure 12. Total phosphorus measurements taken at multiple sites along the stream for four different dates in 2005.

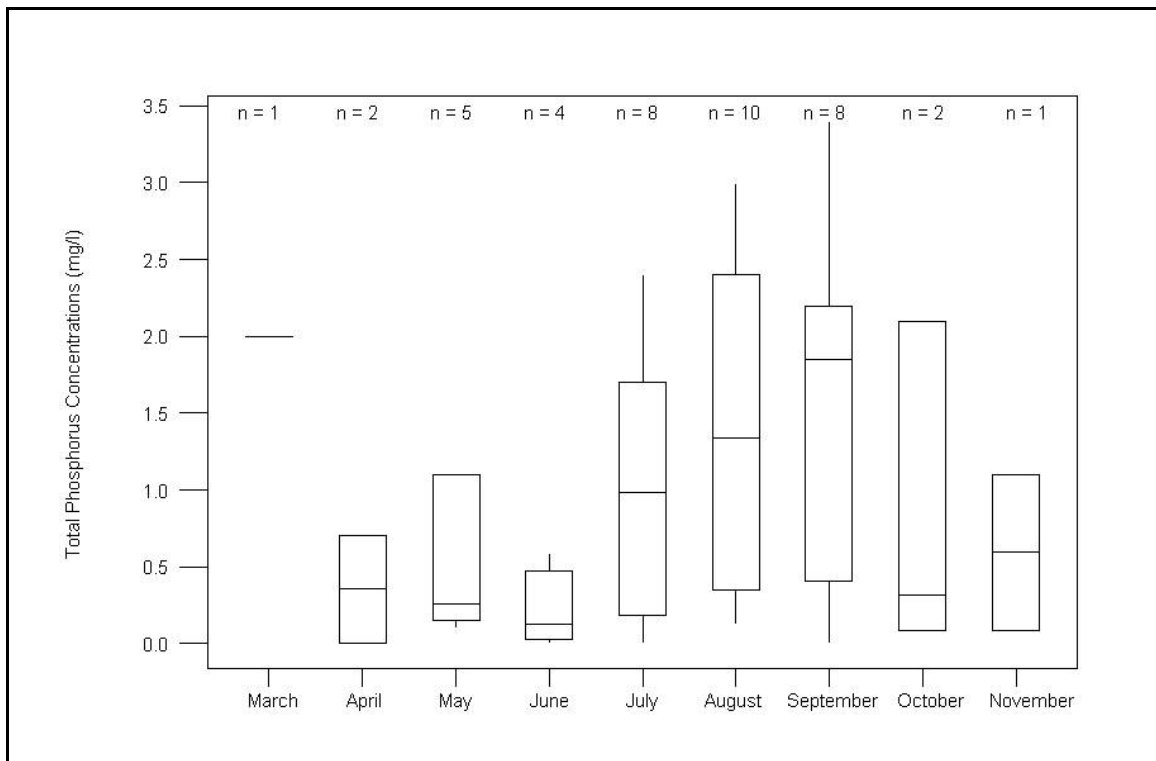


Figure 13. Total phosphorus boxplots by month (all sites combined).

### 3.2. TMDL Target

*General description of the pollutant.* Phosphorus is widely recognized as a primary limiting nutrient for plant growth in freshwater aquatic systems (Kalff, 2002). Under normal conditions, phosphorus is scarce in the environment (USEPA, 1999). Naturally-occurring phosphorus exists in rocks and natural phosphorus deposits in the earth's crust and is released by the processes of weathering, leaching, erosion, and mining. Anthropogenic inputs of phosphorus to aquatic ecosystems include synthetic plant fertilizers and waste materials from industrial, sanitary, and livestock production systems. Phosphorus reaches waterbodies via atmospheric deposition, direct discharge, surface runoff, and erosion (particulate matter/sediment-attached). In freshwater systems, phosphorus exists in either organic or inorganic forms (USEPA, 1999).

*Selection of environmental conditions.* A TMDL must be designed so that state water quality standards are being met at all times, and especially during critical environmental conditions. The critical environmental conditions in Milford Creek occur during sustained warm and dry periods, when no flow is contributed from Lower Gar Lake and conditions are ideal for plant & algal growth. High temperatures reduce the saturation point for dissolved oxygen and create a stressful environment for aquatic life, while reduced streamflow and water velocity allow algae blooms to occur and drive dissolved oxygen levels to extreme levels during the day and below state water quality standards at night. Such conditions occur during the summer months, especially in the months of July, August, and September. To ensure an adequate margin of safety, critical conditions for Milford Creek are deemed to occur between the months of June and October.

*Waterbody pollutant loading capacity (TMDL).* This TMDL was designed as a steady-state or critical condition loading capacity. It defines the maximum amount of total phosphorus that the stream can assimilate under critical environmental conditions and still meet state water quality standards for dissolved oxygen. Under low streamflow conditions, the maximum loading capacity is 7.0 lbs/day total phosphorus. However, under higher streamflow conditions the stream is able to assimilate higher phosphorus loads; thus, the load capacity varies with flow. At peak streamflow, the total maximum daily load is 1,607.4 lbs/day. Appendix C provides information on how these load capacities were determined.

Chronic/long term nutrient enrichment also contributes to the plant growth and algae problems in Milford Creek, since phosphorus is constantly recycled between the water column and various storage sinks such as benthic sediment, vegetation, and organic matter. Therefore, a long term waterbody loading capacity is also provided. The long term total phosphorus loading capacity for Milford Creek is estimated to be 9,221 lbs/year on an average basis.

*Decision criteria for water quality standards attainment.* The criterion to be used for determining attainment of water quality standards is the numeric criteria for dissolved oxygen as defined in Chapter 61[567], Table 2 of the Iowa Administrative Code (IAC, 2006). These standards are described in Section 3.1 of this report. Index of Biotic

Integrity IBI scores for fish and benthic macroinvertebrates in the downstream segment of Milford Creek are also to be used for assessing compliance for 305(b) reporting purposes.

### 3.3. Pollution Source Assessment

*Potential pollutant sources.* Nonpoint sources of phosphorus in the Milford Creek watershed include overland surface runoff from urban and agricultural areas (carrying dissolved and sediment-attached phosphorus), discharges from Lower Gar Lake during wet periods, and atmospheric deposition directly onto the water surface.

Point sources of phosphorus in the Milford Creek watershed include two facilities registered under the National Pollutant Discharge Elimination System: the Iowa Great Lakes Sanitary District wastewater treatment plant and Derner's of Milford animal feeding operation (AFO). The locations of these point sources can be seen in Figure 7 (shown previously), with permit details in Table 3.

**Table 3. NPDES permits in the Milford Creek watershed.**

Name	Permit Type	NPDES #	EPA #	Description
Iowa Great Lakes Sanitary District WWTP	Municipal	30500901	IA0059765	Rotating biological contactor undergoing upgrade to activated sludge
Derner's of Milford AFO	Agricultural	3000010	IA0077593	4000-head beef cattle 80-acre open feedlot

*Existing loading.* Milford Creek carries high phosphorus loads on a regular basis. Measurements taken in the stream during 2001, 2002, 2004, and 2005 sampling show calculated total phosphorus loads ranging from less than 2 lbs/day at the upstream monitoring site up to nearly 200 lbs/day at the downstream monitoring site (n = 34). The median total phosphorus load during sampling periods was 15.1 lbs/day at the upstream site and 90.6 lbs/day at the downstream site.

Based on monitoring data and modeled estimates, the majority of phosphorus in Milford Creek is contributed by point source wastewater inputs. This is especially true in dry years when no lake water is received from Lower Gar Lake. Figures 14 and 15 show the estimated phosphorus contributions to Milford Creek during two alternative years, 2003 and 2004. 2003 was rather dry year, with just 20.4 inches of total rainfall (18<sup>th</sup> percentile for 55 years of data) (IEM, 2007). During that year, phosphorus from wastewater inputs made up 93% of the total annual load in Milford Creek, with the remaining 7% coming from nonpoint source runoff in the immediate drainage area.

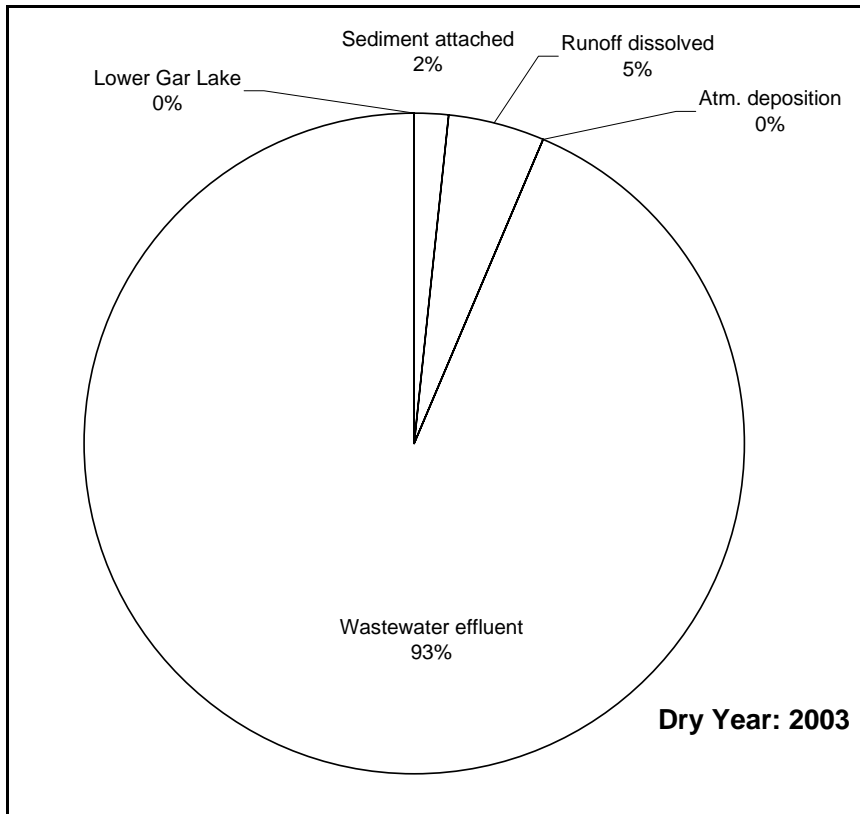


Figure 14. Estimated phosphorus loading by source in 2003.

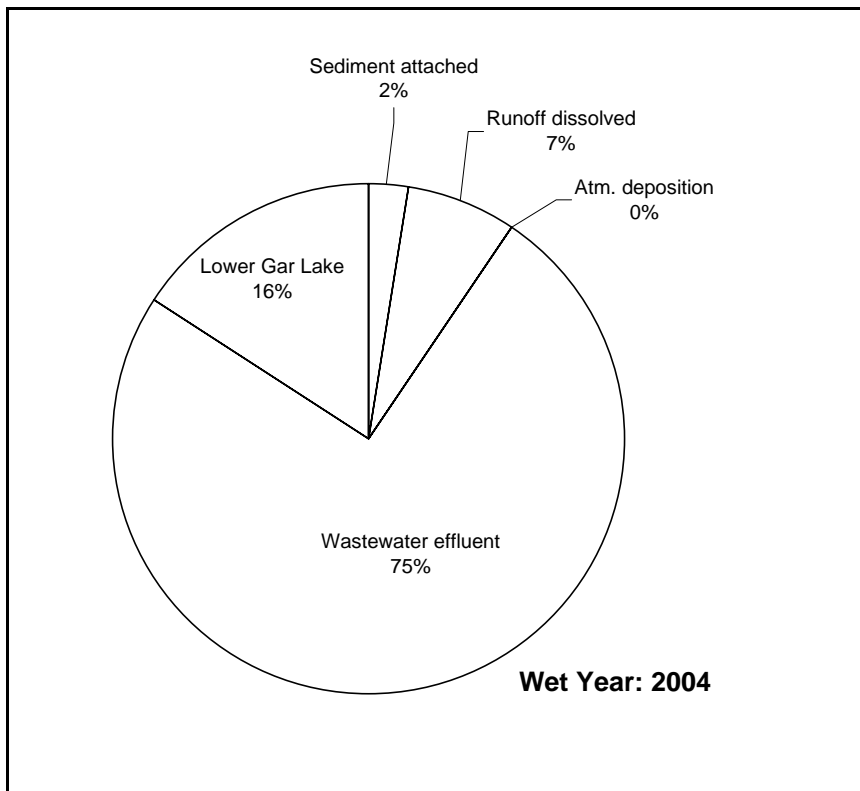


Figure 15. Estimated phosphorus loading by source in 2004.

In 2004, however, 37.7 inches of rain fell in Milford, Iowa (95<sup>th</sup> percentile of 55 years of data) (IEM, 2007). During this year, exports of phosphorus to Milford Creek from Lower Gar Lake contributed 16% of the total annual phosphorus budget, but point source wastewater still made up 75% of the total inputs. Appendices C and E contain information on the methods and assumptions used in estimating existing phosphorus loads for this TMDL.

Based on the study results from Stenback and Crumpton (2006), phosphorus loading from the wastewater treatment plant is relatively constant from year to year, but varies seasonally according to tourism and climate in the Iowa Great Lakes region. Phosphorus loading is affected by the fluctuating human population, being highest in the summer months and lowest in the winter months, while concentrations are influenced by rainwater infiltration and inflow (I&I) into the sewer system. The combination of dry weather (low I&I) and a greater population equivalent explains why both phosphorus concentration and loading from the WWTP are greatest in the summer months, particularly in late summer when critical environmental conditions also occur in the stream (Figures 16 and 17). Overall, the total phosphorus output from the IGLSD WWTP averages 66.2 lbs/day, with highs in summer time reaching 91.8 lbs/day.

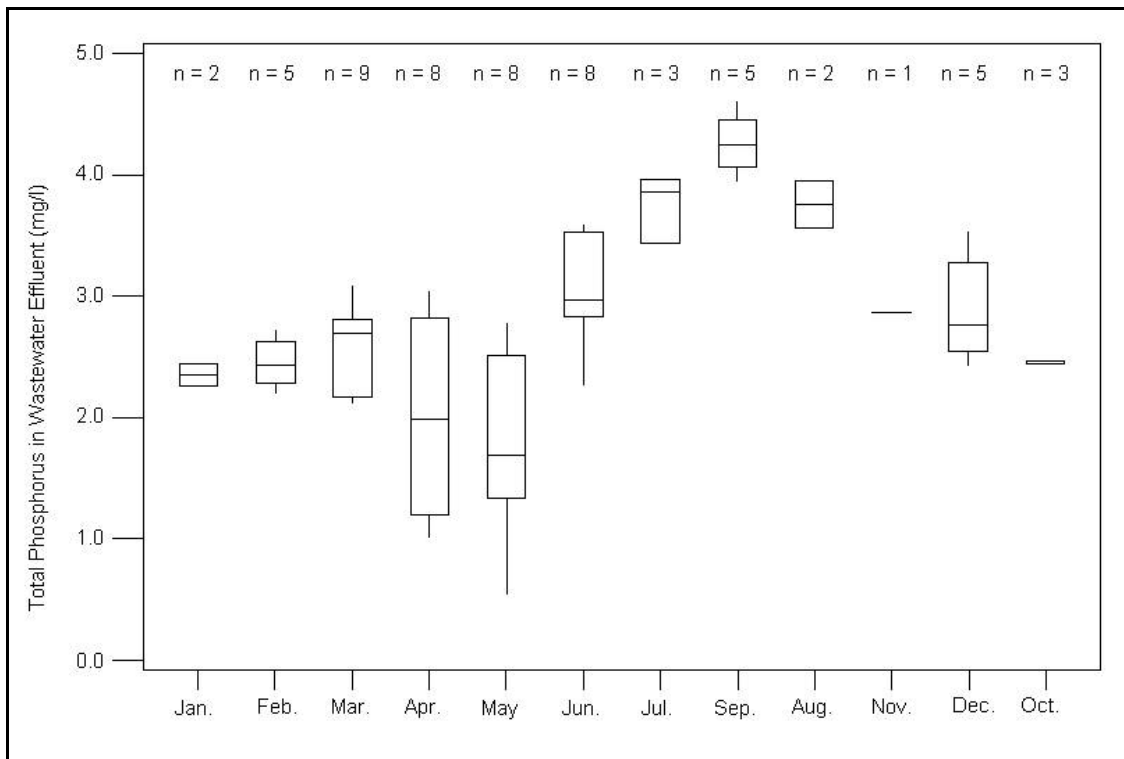


Figure 16. Monthly boxplots of total phosphorus measured in IGLSD WWTP effluent.

*Departure from load capacity.* During critical environmental conditions, phosphorus loads in Milford Creek are as high as 91.8 lbs/day. The Total Maximum Daily Load for Milford Creek to attain water quality standards under these same conditions is 7 lbs/day

total phosphorus. This would necessitate a 92.5% reduction in total phosphorus loading during dry period flows.

*Allowance for increases in pollutant loads.* The IGLSD wastewater treatment plant is currently constructing a new, upgraded facility. There are also significant efforts underway in the upper Iowa Great Lakes watershed to use stormwater best management practices and low-impact development in existing and expanding urban areas. Therefore, a future allowance for potential increases in phosphorus loading was deemed not necessary for this TMDL.

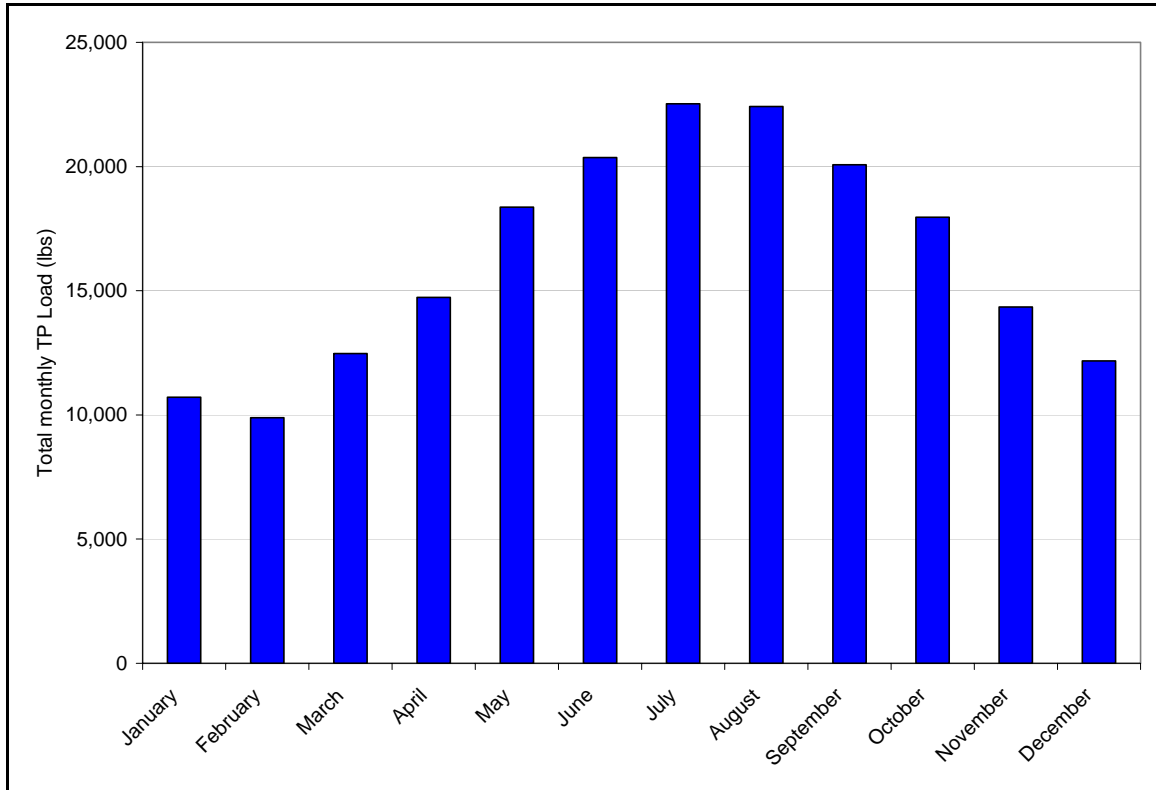


Figure 17. Modeled total phosphorus loading from IGLSD WWTP by month.

### 3.4. Pollutant Allocation

*Wasteload allocation.* The wasteload allocation (WLA) represents the fraction of the total allowable pollutant load that can be attributed to permitted point sources. In this TMDL, it was determined using the Qual2K stream model under critical environmental conditions. During low streamflow periods, the wasteload allocation for total phosphorus is 6.9 lbs/day.

This WLA is based on meeting a target concentration in wastewater (0.5 mg/l TP), thus loads will vary depending on flow conditions. Under high flow conditions, the total phosphorus wasteload would be 42.8 lbs/day (Table 4). Stream modeling to determine this WLA was done using existing permit limits for CBOD5, ammonia, and other

parameters under the assumption that those pollutants will remain constant in future permit issuances, with no reductions being necessary.

**Table 4. Total phosphorus wasteload allocation for the Iowa Great Lakes Sanitary District WWTP.**

Name	Max. Total Phosphorus Concentration	Min. Critical Conditions Flow (MGD) and TP WLA (lbs/day)	ADW Flow <sup>†</sup> (MGD) and TP WLA (lbs/day)	AWW Flow <sup>†</sup> (MGD) and TP WLA (lbs/day)	MWW Flow <sup>†</sup> (MGD) and TP WLA (lbs/day)
IGLSD WWTP	0.5 mg/l or 500 µg/l	1.645 MGD 6.9 lbs/day	2.22 MGD 9.3 lbs/day	5.17 MGD 21.6 lbs/day	10.26 MGD 42.8 lbs/day

<sup>†</sup>Design flows for new activated sludge plant construction permit. ADW = Average dry weather; AWW = Average wet weather; MWW = Max wet weather.

Permitted animal feeding operations are not allowed to discharge to surface waterbodies; rather, NPDES regulations require that they employ practices such as runoff holding ponds to retain event-driven pollutants on site. Derner's of Milford employs both a runoff holding pond and solids settling diversion to capture and infiltrate stormwater runoff. Therefore, it receives a wasteload allocation of zero.

*Load allocation.* The load allocation (LA) represents the fraction of the total allowable pollutant load attributed to nonpoint sources. Under low streamflow conditions, the total phosphorus load allocation is 0.1 lbs/day, including background loading from atmospheric deposition. This value was derived using monitored data from the drainage ditch and tributary which feed Milford Creek, both of which barely flow and contain little phosphorus during dry weather periods.

Under high flows, nonpoint source phosphorus loads may dominate over point source loads. Peak flows received from Lower Gar Lake and runoff from the immediate watershed may exceed 600 cfs (Stenback and Crumpton, 2006 and Appendix C). Under these conditions, the maximum load allocation for nonpoint sources is 1,564.6 lbs/day.

The long term nonpoint source load allocation is set at 2,813 lbs/year (on average). This value was set based on reducing nonpoint source loading to a level that is equivalent to the reductions called for in the 2003 Lower Gar Lake TMDL report, i.e. a 50% reduction in phosphorus loading.

*Margin of safety.* The margin of safety (MOS) for this TMDL is implicit based on conservative assumptions applied in modeling to define the allowable pollutant loading. By establishing the TMDL and WLA using a concentration-based target at critical environmental conditions, it is ensured that water quality standards will be met at all

other times of the year when receiving flows are higher and conditions are less suitable for algal response to dissolved phosphorus loads.

### **3.5. Reasonable Assurance**

When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint source load reductions will occur, EPA's 1991 TMDL Guidance states that the TMDL should provide reasonable assurances that nonpoint source control measures will achieve expected load reductions. Based on modeling for this TMDL, reductions in total phosphorus loading from the IGLSD wastewater treatment plant can allow the lower segment of Milford Creek to meet and maintain numeric criteria for dissolved oxygen; however, the wasteload allocations are not sufficient to achieve water quality standards in the upstream segment of Milford creek which is altered by flow restrictions at the Lower Gar Lake dam.

The 2003 TMDL for Lower Gar Lake outlines a plan to reduce phosphorus loading and achieve water quality standards in that lake, which would in turn help water quality in Milford Creek. In 2006, encouraged by additional state funding for lake restoration, 127 of Iowa's principal public lakes were ranked for lake restoration suitability based upon a number of socio-economic, water quality, watershed factors. The ranking process resulted in a priority list of thirty-five lakes, of which Lower Gar Lake is one. Reduction of the phosphorus load from Lower Gar Lake is critical, as it is the dominant nonpoint source to Milford Creek.

Additionally, in recent years there have been substantial efforts in the Iowa Great Lakes region to improve and protect water quality, educate landowners and citizens about water quality issues, and reduce nutrient delivery to the lakes. Innovative stormwater management and low impact development, extensive water monitoring, and numerous activist groups provide evidence of the region's devotion to enhancing and protecting their water resources. Technical and financial assistance available from the IDNR Watershed Improvement Section and IDALS Division of Soil Conservation provide the economic potential for local groups to achieve the load reductions called for in this report.

### **3.6. TMDL Summary**

The following equation represents the Total Maximum Daily Load (TMDL) and its components for total phosphorus in Milford Creek:

$$TMDL = Point\ source\ WLA + Nonpoint\ source\ LA + Margin\ of\ Safety$$

Under critical environmental conditions,

$$7.0\ lbs/day = 6.9\ lbs/day + 0.1\ lbs/day + Implicit\ MOS$$

Under high flows,

$$1,607.4 \text{ lbs/day} = 42.8 \text{ lbs/day} + 1,565.6 \text{ lbs/day} + \text{Implicit MOS}$$

On a long term average basis,

$$9,221 \text{ lbs/year} = 6,408 \text{ lbs/year} + 2,813 \text{ lbs/year} + \text{Implicit MOS}$$

## 4. Implementation Plan

This implementation plan is not a requirement of the Federal Clean Water Act. However, the Iowa Department of Natural Resources recognizes that technical guidance and support are critical to achieving the goals outlined in this TMDL. The plan may be useful to local professionals, watershed managers, and citizens for decision-making support and planning purposes.

### 4.1. General Approach

Removing the impairment from Milford Creek will take extensive effort and cooperation by multiple stakeholders. Reductions in phosphorus loading to the stream will generate immediate benefits in the downstream segment, but may take time in the upper portion as bed and bank storage sinks are gradually depleted through nonpoint source reductions. A combination of strategic management actions can, with time, help restore Milford Creek to a healthy ecosystem able to support diverse aquatic life.

Improving water quality conditions in the upstream segment of Milford Creek is problematic due to its altered hydrology and shallow lake-like conditions. These environmental conditions prohibit the upstream segment from meeting water quality standards through wasteload reductions alone. Because the Federal Clean Water Act does not give authority to regulate nonpoint sources of pollution, an adaptive management approach is recommended to evaluate tradeoffs and effectiveness of alternative management actions in the upper portion of Milford Creek.

### 4.2. Strategies

*Reduce phosphorus inputs from wastewater.* On a long term basis, it is estimated that point source wastewater contributes over 80% of the total phosphorus load to Milford Creek. Because of the channel's shallow depth, wide channel, and low gradient, significant reductions in phosphorus are necessary to limit algal growth to levels consistent with meeting water quality standards. As modeling for the TMDL demonstrates, critical concentrations of total phosphorus in wastewater effluent would need to be reduced to 0.5 mg/l or less to meet minimum dissolved oxygen standards in the stream.

The Clean Water Act requires that effluent limits in NPDES permits be consistent with "the assumptions and requirements of any available WLA" in an approved TMDL. Therefore, reductions in phosphorus loading from the IGLSD wastewater treatment plant will be made in accordance with the wasteload allocations proposed in this TMDL via future NPDES permit limits. Information on phosphorus removal using biological, chemical, and filtration technologies is available from the U.S. EPA (USEPA, 2007).

*Reduce phosphorus loading from watershed nonpoint sources and Lower Gar Lake.* Nonpoint sources of phosphorus to Milford Creek also need to be reduced significantly in order to meet water quality standards in the upper segment. Depending on a number of

factors, surface runoff received from the watershed or flows over the dam from Lower Gar Lake may dominate phosphorus loading to Milford Creek from nonpoint sources. Therefore, a combination of management strategies is necessary to effectively deal with nonpoint source loading.

In the immediate watershed drainage area to Milford Creek (excluding the Iowa Great Lakes), it is estimated that the dominant source of phosphorus is urban land. Urban areas generally have a higher rate of phosphorus export (per unit area) than rural areas due to the higher concentration of humans, pets, and their associated activities (USEPA, 1999). A variety of urban stormwater best management practices (BMPs) are being used in the Iowa Great Lakes region and should be further expanded to reduce urban pollutant loading to Milford Creek.

Portions of the total nonpoint source phosphorus load also come from agricultural areas in the watershed. Fertilizer and manure application should be carefully timed and incorporated into the soil when/where possible, and management practices which reduce surface runoff and promote infiltration during heavy rains should be utilized. Sediment erosion practices can also be effective, since phosphorus adsorbs to sediment particles and can be released to the stream water column under anaerobic conditions. Figures 18 and 19 depict the estimated nonpoint source loading areas for total phosphorus and sediment delivery in the Milford Creek watershed.

Phosphorus loading from Lower Gar Lake and the upper Iowa Great Lakes will be most effectively reduced through a combination of lake management activities and watershed loading reductions in the upper Iowa Great Lakes. The TMDL report for Lower Gar Lake provides a plan for reducing phosphorus loading to this lake and its watershed.

*Investigate and implement alternative management actions.* A single-tracked approach to improving water quality in Milford Creek will likely be unsuccessful. Reductions in phosphorus loading are needed to limit algal growth and improve dissolved oxygen levels, but restoring the overall health of the ecosystem may require or be better achieved through physical and biological improvements to the stream channel. This is especially true along the upstream segment of Milford Creek.

Alternative management actions may include planting trees in the riparian zone for shade and temperature reduction, harvesting and removal of aquatic plant biomass, and channel deepening. Such practices, done in concert with nutrient reductions, will have a positive impact on dissolved oxygen levels by limiting environmental factors for algal growth. Trees provide shade and cooler water temperatures which limit plant growth, and the harvesting aquatic plant biomass permanently removes stored nutrients which would otherwise be recycled back into the ecosystem. Channel deepening/dredging could possibly improve bed gradient and stream velocity, increase channel storage, remove benthic phosphorus, and limit light penetration to benthic algae. Finally, removing the old rock/debris dam below the Lower Gar Lake dam to prevent fish entrapment could help eliminate unsightly fish kills during drought periods. Obviously, a cost-benefit analysis to determine the effectiveness of various alternatives would be needed.

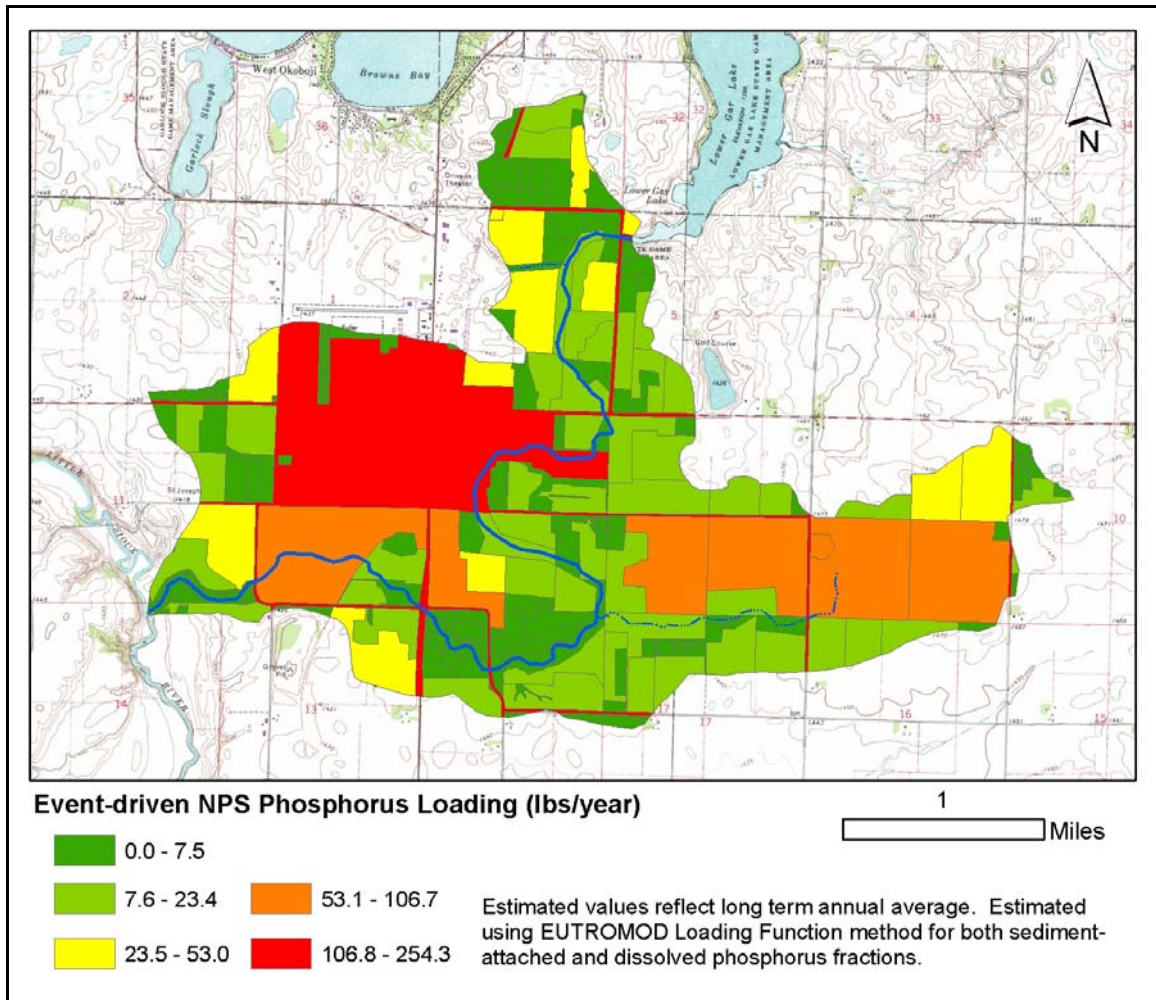


Figure 18. Estimated annual phosphorus loads delivered from nonpoint sources.

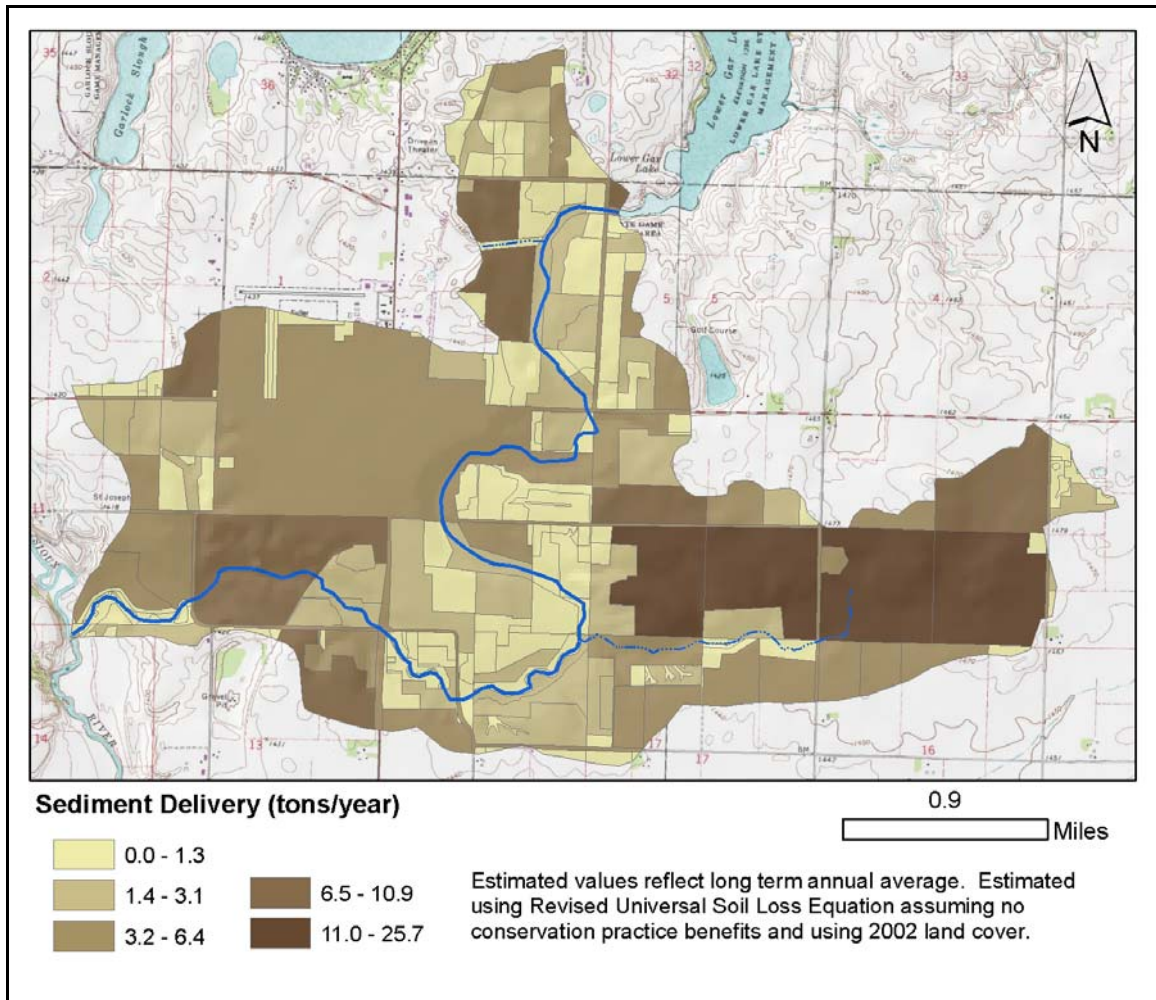


Figure 19. Estimated sediment delivery to Milford Creek. Phosphorus attached to sediment can be released to the water column under anoxic conditions.

## **5. Future Monitoring**

Further monitoring is needed in Milford Creek to follow-up on the implementation of the TMDL. Water quality monitoring is a critical element in understanding the current conditions and natural variations of water resources. Furthermore, monitoring is necessary to track changes in water quality and the effectiveness of improvements made in the watershed.

### **5.1. Monitoring Plan to Track TMDL Effectiveness**

The Iowa DNR TMDL program is committed to monitoring waters where TMDLs have been completed, and follow-up chemical and biological monitoring will be conducted through the Watershed Improvement and Watershed Monitoring and Assessment Sections. This monitoring will, at a minimum, meet the minimum data requirements established by Iowa's 305(b) guidelines for a complete water quality assessment. Biological samples and continuous dissolved oxygen data will be collected by 2012.

Monitoring at the IGLSD facility will continue as required by NPDES permit. Currently, monitoring includes reporting CBOD5 and ammonia three times per week and average flow on a daily basis, plus various other parameters. Although not required to report the data, the IGLSD performs additional monitoring for effluent dissolved oxygen and other parameters. Future monitoring requirements may include dissolved oxygen, total phosphorus, and total nitrogen.

### **5.2. Supplemental Water Monitoring Plan for Local Stakeholders**

The purpose of this section is to outline what an appropriate monitoring plan would look like for Milford Creek should any watershed monitoring groups become active and aspire to collect water quality data in the future. Financial and logistical constraints may prohibit full deployment of this plan, but if resources allow it would provide a rather comprehensive dataset for assessment purposes. Local knowledge should drive the more specific details of all future monitoring efforts.

To adequately monitor the stream's health as it relates to the 303(d) biological impairment, there are five major components that are needed. These five components are listed in Table 5, along with more specific details on the parameters, locations, and sampling frequencies. Interested groups or citizens should contact the Iowa DNR Watershed Monitoring and Assessment Section for technical assistance and training.

**Table 5. Proposed monitoring plan for Milford Creek.**

Component	Sample Frequency	Locations	Parameters/Details
1. Point source phosphorus monitoring	Once per week	Final effluent of IGLSD WWTP	Grab sample for total phosphorus and dissolved phosphorus, to be implemented into NPDES permit monitoring requirements
2. Water chemistry sampling	Bi-weekly from March to November	STORET sites #11300001, #11300012, #11300015, #11300002	All common parameters listed in Appendix A of the Iowa Water Monitoring Plan 2000 ( <a href="http://wqm.igsb.uiowa.edu/publications/plan2000.htm">http://wqm.igsb.uiowa.edu/publications/plan2000.htm</a> )
3. Biological and physical habitat assessments	Annually, at low-flow conditions	STORET sites #11300001, #11300002	Monitoring should be done in accordance with the <i>Biological Assessment of Iowa's Streams and Habitat Evaluation Procedures for Wadeable Streams and Rivers in Iowa</i> available from the IDNR Watershed Monitoring and Assessment Section.
4. Continuous dissolved oxygen and flow measurements	Continuously (6-minute intervals) from June to October	STORET sites #11300001, #11300012, #11300015, #11300002	Continuous streamflow and dissolved oxygen autosampler deployment according to UHL protocols
5. "Snapshot" monitoring	Twice per summer; once during early season high flows and once in late season low flows	2005 sampling locations shown in Figure 10	To serve needs of Qual2K modeling, collect all common water chemistry parameters (see #2) at each site when a full 24-hour period of continuous dissolved oxygen data is available for all continuous monitoring sites (see #4). Also, physical parameters to be collected at each stream site include streamflow, avg. width, avg. depth, and avg. velocity.

## **6. Public Participation**

The draft TMDL for Milford Creek was presented at a public meeting at the Iowa Great Lakes Maritime Museum on January 19, 2005. Based on comments received during this public meeting, the TMDL was delayed to collect and analyze additional data. The revised TMDL will again be made available for public comment prior to submittal to EPA. Comments received will be reviewed and given consideration for incorporation in the final TMDL.

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## 8. Appendices

### Appendix A --- Glossary of Terms and Acronyms

<b>303(d) list:</b>	Refers to section 303(d) of the Federal Clean Water Act, which requires a listing of all public surface water bodies (creeks, rivers, wetlands, and lakes) that do not support their general and/or designated uses. Also called the state's "Impaired Waters List."
<b>305(b) assessment:</b>	Refers to section 305(b) of the Federal Clean Water Act, it is a comprehensive assessment of the state's public water bodies ability to support their general and designated uses. Those bodies of water which are found to be not supporting or just partially supporting their uses are placed on the 303(d) list.
<b>319:</b>	Refers to Section 319 of the Federal Clean Water Act, the Nonpoint Source Management Program. Under this amendment, States receive grant money from EPA to provide technical & financial assistance, education, & monitoring to implement local nonpoint source water quality projects.
<b>AFO:</b>	Animal Feeding Operation. A livestock operation, either open or confined, where animals are kept in small areas (unlike pastures) allowing manure and feed become concentrated.
<b>Base flow:</b>	The fraction of discharge (flow) in a river which comes from ground water.
<b>BMIBI:</b>	Benthic Macroinvertebrate Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of bottom-dwelling invertebrates.
<b>BMP:</b>	Best Management Practice. A general term for any structural or upland soil or water conservation practice. For example terraces, grass waterways, sediment retention ponds, reduced tillage systems, etc.
<b>CAFO:</b>	Confinement Animal Feeding Operation. An animal feeding operation in which livestock are confined and totally covered by a roof, and not allowed to discharge manure to a water of the state.
<b>Credible data law:</b>	Refers to 455B.193 of the Iowa Administrative Code, which ensures that water quality data used for all purposes of the Federal Clean Water Act are sufficiently up-to-date and accurate.

<b>Cyanobacteria (blue-green algae):</b>	Members of the phytoplankton community that are not true algae but can photosynthesize. Some species can be toxic to humans and pets.
<b>Designated use(s):</b>	Refer to the type of economic, social, or ecologic activities that a specific water body is intended to support. See Appendix B for a description of all general and designated uses.
<b>DNR (or IDNR):</b>	Iowa Department of Natural Resources.
<b>Ecoregion:</b>	A system used to classify geographic areas based on similar physical characteristics such as soils and geologic material, terrain, and drainage features.
<b>EPA (or USEPA):</b>	United States Environmental Protection Agency.
<b>FIBI:</b>	Fish Index of Biotic Integrity. An index-based scoring method for assessing the biological health of streams and rivers (scale of 0-100) based on characteristics of fish species.
<b>FSA:</b>	Farm Service Agency (United States Department of Agriculture). Federal agency responsible for implementing farm policy, commodity, and conservation programs.
<b>General use(s):</b>	Refer to narrative water quality criteria that all public water bodies must meet to satisfy public needs and expectations. See Appendix B for a description of all general and designated uses.
<b>GIS:</b>	Geographic Information System(s). A collection of map-based data and tools for creating, managing, and analyzing spatial information.
<b>Gully erosion:</b>	Soil movement (loss) that occurs in defined upland channels and ravines that are typically too wide and deep to fill in with traditional tillage methods.
<b>HEL:</b>	Highly Erodible Land. Defined by the USDA Natural Resources Conservation Service (NRCS), it is land which has the potential for long term annual soil losses to exceed the tolerable amount by eight times for a given agricultural field.

<b>IGLSD:</b>	Iowa Great Lakes Sanitary District. Municipal sewage treatment plant located in Milford, Iowa that discharges to Milford Creek.
<b>Integrated report:</b>	Refers to a comprehensive document which combines the 305(b) assessment with the 303(d) list, as well as narratives and discussion of overall water quality trends in the state's public water bodies. The Iowa Department of Natural Resources submits an integrated report to the EPA biennially in even numbered years.
<b>LA:</b>	Load Allocation. The fraction of the total pollutant load of a water body which is assigned to all combined <i>nonpoint sources</i> in a watershed. (The total pollutant load is the sum of the waste load and load allocations.)
<b>Load:</b>	The total amount (mass) of a particular pollutant in a waterbody.
<b>MOS:</b>	Margin of Safety. In a total maximum daily load (TMDL) report, it is a set-aside amount of a pollutant load to allow for any uncertainties in the data or modeling.
<b>MS4 Permit:</b>	Municipal Separate Storm Sewer System Permit. An NPDES license required for some cities and universities which obligates them to ensure adequate water quality and monitoring of runoff from urban storm water and construction sites, as well as public participation and outreach.
<b>Nonpoint source pollution:</b>	A collective term for contaminants which originate from a diffuse source.
<b>NPDES:</b>	National Pollution Discharge Elimination System, which allows a facility (e.g. an industry, or a wastewater treatment plant) to discharge to a water of the United States under regulated conditions.
<b>NRCS:</b>	Natural Resources Conservation Service (United States Department of Agriculture). Federal agency which provides technical assistance for the conservation and enhancement of natural resources.
<b>Periphyton:</b>	Algae that are attached to substrates (rocks, sediment, wood, and other living organisms).
<b>Phytoplankton:</b>	Collective term for all self-feeding (photosynthetic) organisms which provide the basis for the aquatic food chain. Includes many types of algae and cyanobacteria.

<b>Point source pollution:</b>	A collective term for contaminants which originate from a specific point, such as an outfall pipe. Point sources are generally regulated by an NPDES permit.
<b>PPB:</b>	Parts per Billion. A measure of concentration which is the same as micrograms per liter (µg/l).
<b>PPM:</b>	Parts per Million. A measure of concentration which is the same as milligrams per liter (mg/l).
<b>Riparian:</b>	Refers to site conditions that occur near water, including specific physical, chemical, and biological characteristics that differ from upland (dry) sites.
<b>RUSLE:</b>	Revised Universal Soil Loss Equation. An empirical model for estimating long term, average annual soil losses due to sheet and rill erosion.
<b>Secchi disk:</b>	A device used to measure transparency in water bodies. The greater the secchi depth (measured in meters), the more transparent the water.
<b>Sediment delivery ratio:</b>	A value, expressed as a percent, which is used to describe the fraction of gross soil erosion which actually reaches a water body of concern.
<b>Seston:</b>	All particulate matter (organic and inorganic) in the water column.
<b>Sheet &amp; rill erosion</b>	Soil loss which occurs diffusely over large, generally flat areas of land.
<b>SI:</b>	Stressor Identification. A process by which the specific cause(s) of a biological impairment to a water body can be determined from cause-and-effect relationships.
<b>Storm flow (or stormwater):</b>	The fraction of discharge (flow) in a river which arrived as surface runoff directly caused by a precipitation event. <i>Storm water</i> generally refers to runoff which is routed through some artificial channel or structure, often in urban areas.
<b>STP:</b>	Sewage Treatment Plant. General term for a facility that processes municipal sewage into effluent suitable for release to public waters.

<b>SWCD:</b>	Soil and Water Conservation District. Agency which provides local assistance for soil conservation and water quality project implementation, with support from the Iowa Department of Agriculture and Land Stewardship.
<b>TMDL:</b>	Total Maximum Daily Load. As required by the Federal Clean Water Act, a comprehensive analysis and quantification of the maximum amount of a particular pollutant that a water body can tolerate while still meeting its general and designated uses.
<b>TSI (or Carlson's TSI):</b>	Trophic State Index. A standardized scoring system (scale of 0-100) used to characterize the amount of algal biomass in a lake or wetland.
<b>TSS:</b>	Total Suspended Solids. The quantitative measure of seston, all materials, organic and inorganic, which are held in the water column.
<b>Turbidity:</b>	The degree of cloudiness or murkiness of water caused by suspended particles.
<b>UAA:</b>	Use Attainability Analysis. A protocol used to determine which (if any) designated uses apply to a particular water body. (See Appendix B for a description of all general and designated uses.)
<b>UHL:</b>	University Hygienic Laboratory (University of Iowa). Provides physical, biological, and chemical sampling for water quality purposes in support of beach monitoring and impaired water assessments.
<b>USGS:</b>	United States Geologic Survey (United States Department of the Interior). Federal agency responsible for implementation and maintenance of discharge (flow) gauging stations on the nation's water bodies.
<b>Watershed:</b>	The land (measured in units of surface area) which drains water to a particular body of water or outlet.
<b>WLA:</b>	Waste Load Allocation. The fraction of waterbody loading capacity assigned to point sources in a watershed. Alternatively, the allowable pollutant load that an NPDES permitted facility may discharge without exceeding water quality standards.

<b>WQS:</b>	Water Quality Standards. Defined in Chapter 61 of Environmental Protection Commission [567] of the Iowa Administrative Code, they are the specific criteria by which water quality is gauged in Iowa.
<b>WWTP:</b>	Waste Water Treatment Plant. General term for a facility which processes municipal, industrial, or agricultural waste into effluent suitable for release to public waters or land application.
<b>Zooplankton:</b>	Collective term for all animal plankton which serve as secondary producers in the aquatic food chain and the primary food source for larger aquatic organisms.

## Appendix B --- General and Designated Uses of Iowa's Waters

### Introduction

Iowa's water quality standards (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code) provide the narrative and numerical criteria by which water bodies are judged when determining the health and quality of our aquatic ecosystems. These standards vary depending on the type of water body (lakes vs. rivers) and the assigned uses (general use vs. designated uses) of the water body that is being dealt with. This appendix is intended to provide information about how Iowa's water bodies are classified and what the use designations mean, hopefully providing a better general understanding for the reader.

All public surface waters in the state are protected for certain beneficial uses, such as livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and other incidental uses (e.g. withdrawal for industry and agriculture). However, certain rivers and lakes warrant a greater degree of protection because they provide enhanced recreational, economical, or ecological opportunities. Thus, all public bodies of surface water in Iowa are divided into two main categories: *general* use segments and *designated* use segments. This is an important classification because it means that not all of the criteria in the state's water quality standards apply to all water ways; rather, the criteria which apply depend on the use designation & classification of the water body.

### General Use Segments

A general use segment water body is one which does not maintain perennial (year-round) flow of water or pools of water in most years (i.e. ephemeral or intermittent waterways). In other words, stream channels or basins which consistently dry up year after year would be classified as general use segments. Exceptions are made for years of extreme drought or floods. For the full definition of a general use water body, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

General use waters are protected for the beneficial uses listed above, which are: livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, and industrial, agricultural, domestic and other incidental water withdrawal uses. The criteria used to ensure protection of these uses are described in section 61.3(2) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

### Designated Use Segments

Designated use segments are water bodies which maintain flow throughout the year, or at least hold pools of water which are sufficient to support a viable aquatic community (i.e. perennial waterways). In addition to being protected for the same beneficial uses as the general use segments, these perennial waters are protected for more specific activities such as primary contact recreation, drinking water sources, or cold-water fisheries. There are a total of thirteen different designated use classes (Table B1) which may apply, and a

water body may have more than one designated use. For definitions of the use classes and more detailed descriptions, consult section 61.3(1) in the state's published water quality standards, which became effective on March 22, 2006 (Environmental Protection Commission [567], Chapter 61 of the Iowa Administrative Code).

**Table B1. Designated use classes for Iowa water bodies.**

Class prefix	Class	Designated use	Brief comments
A	A1	Primary contact recreation	Supports swimming, water skiing, etc.
	A2	Secondary contact recreation	Limited/incidental contact occurs, such as boating
	A3	Children's contact recreation	Urban/residential waters that are attractive to children
B	B(CW1)	Cold water aquatic life – Type 2	Able to support coldwater fish (e.g. trout) populations
	B(CW2)	Cold water aquatic life – Type 2	Typically unable to support consistent trout populations
	B(WW-1)	Warm water aquatic life – Type 1	Suitable for game and nongame fish populations
	B(WW-2)	Warm water aquatic life – Type 2	Smaller streams where game fish populations are limited by physical conditions & flow
	B(WW-3)	Warm water aquatic life – Type 3	Streams that only hold small perennial pools which extremely limit aquatic life
	B(LW)	Warm water aquatic life – Lakes and Wetlands	Artificial and natural impoundments with "lake-like" conditions
C	C	Drinking water supply	Used for raw potable water
Other	HQ	High quality water	Waters with exceptional water quality
	HQR	High quality resource	Waters with unique or outstanding features
	HH	Human health	Fish are routinely harvested for human consumption

## Appendix C --- Modeling and Methods

### TMDL Modeling Approach

*Introduction.* The water quality model used in the development of this TMDL was Qual2K. This model assumes steady state hydraulics, constant wasteloads, complete mixing in the stream, and one-dimensional advection and dispersion along the longitudinal axis of the stream. The stream was divided into ten reaches with a varying number of computational elements in each reach. Throughout its length, each reach is assumed to have the same slope, cross-section, channel roughness, re-aeration rate, and biological rate constants. Each computational element is assumed to be a well-mixed reactor and these are strung together sequentially to represent the stream reaches. For a full description and user's manual on Qual2K, visit the EPA's website:

<http://www.epa.gov/athens/wwqtsc/html/qual2k.html>.

*Calibration.* The model was calibrated to the physical conditions in Milford Creek for a representative date (8/31/2005) when the stream was at critical conditions: low streamflow, when wastewater effluent made up the majority of streamflow, stable weather conditions, and available monitoring data. Parameters in the model were adjusted until the predicted results compared favorably with data collected in the stream that day. The calibrated model would then be used to analyze the outcome of implementing alternative WLA scenarios for total phosphorus by assessing the effect on algal growth and dissolved oxygen concentrations downstream. The results of this analysis would be used to identify the target wastewater total phosphorus concentration needed to meet and maintain dissolved oxygen water quality standards in Milford Creek during critical conditions.

Figure D1 shows how Milford Creek was divided into reaches or segments for the model. Monitoring data from Site 50 was used to define headwater boundary conditions while data collected at the IGLSD wastewater treatment plant, storm drainage ditch, and tributary sites were used to define surface water inflows to the stream. Because it was modeled during critical conditions, there was very little inflow to the stream other than IGLSD wastewater. Weather data was obtained from the Iowa Environmental Mesonet (IEM, 2007). Monitoring data for sites 49, 2, and 3 were used to compare model results to measured data and to adjust the model parameters during the calibration procedure. Tables D1 and D2 list the parameters that were adjusted during the calibration.

Figure D2 depicts the model's performance for two important physical parameters: velocity and depth. Figures D3 and D4 depict the longitudinal (lengthwise from upstream to downstream) model performance of stream temperature and dissolved oxygen, while Figures D5 and D6 depict the diurnal (24-hour) model performance for these same two parameters at Site 3.

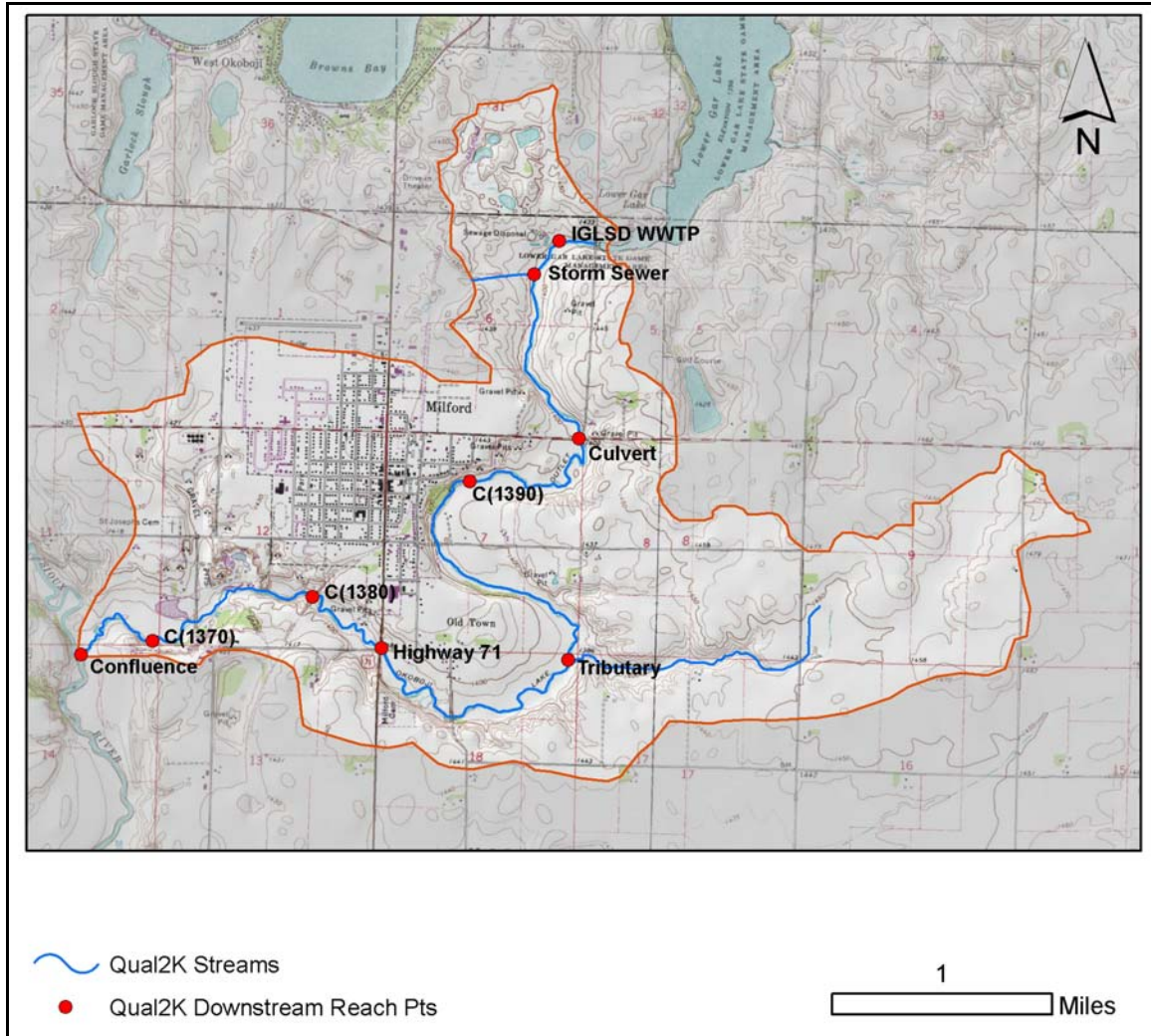


Figure D1. Segmentation of Milford Creek for Qual2K model.

**Table D1. Calibration parameters for Qual2K “Rates” sheet.**

Parameter	Default Value	Calibrated Value
<b>Inorganic suspended solids:</b>		
Settling velocity	0.3	2
<b>Oxygen:</b>		
Reaeration model	User specified	USGS(channel-control)
<b>Slow CBOD:</b>		
Hydrolysis rate	0.1	2
<b>Fast CBOD:</b>		
Oxidation rate	0.23	6
<b>Ammonium:</b>		
Nitrification	1	2
<b>Nitrate:</b>		
Denitrification	0	1
<b>Organic P:</b>		
Hydrolysis	0.2	0.25
<b>Phytoplankton:</b>		
Respiration rate	0.2	0.1
Death rate	0.2	0.1
Nitrogen half sat constant	25	1
Phosphorus half sat constant	5	0.14
Light constant	100	35
Ammonia preference	25	80
Settling velocity	0.5	0.15
<b>Bottom Algae:</b>		
Max Growth rate	50	200
Respiration rate	0.1	0.5
Excretion rate	0.05	0.1
Temp correction	1.07	0.15
Death rate	0.1	0.05
Light constant	100	50
Subsistence quota for nitrogen	0.72	1.5
Subsistence quota for phosphorus	0.1	0.3
Maximum uptake rate for nitrogen	72	720
Maximum uptake rate for phosphorus	5	100
Internal nitrogen half sat constant	0.9	9
Internal phosphorus half sat constant	0.13	1.3
<b>Detritus (POM):</b>		
Dissolution rate	0.5	1.7
Settling velocity	0.1	1
<b>Inorganic suspended solids:</b>		
Settling velocity	0.3	2

**Table D2. Calibration parameters for Qual2K “Light and Heat” sheet.**

Parameter	Default Value	Calibrated Value
<b>Downwelling atmospheric longwave IR radiation</b>		
atmospheric longwave emissivity model	Brunt	Brutsaert
<b>Sediment heat parameters</b>		
Sediment thermal thickness	15	10
Sediment heat capacity	0.4	1

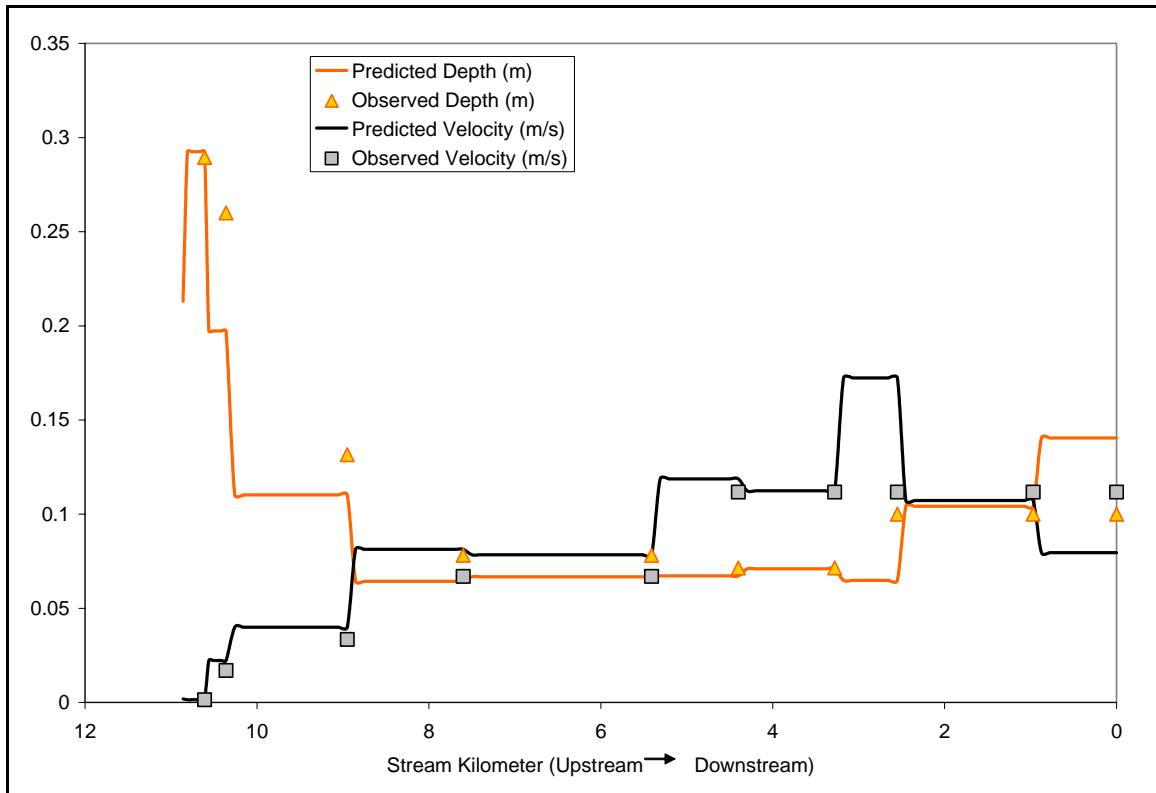


Figure D2. Model performance for hydraulic depth and avg. velocity.

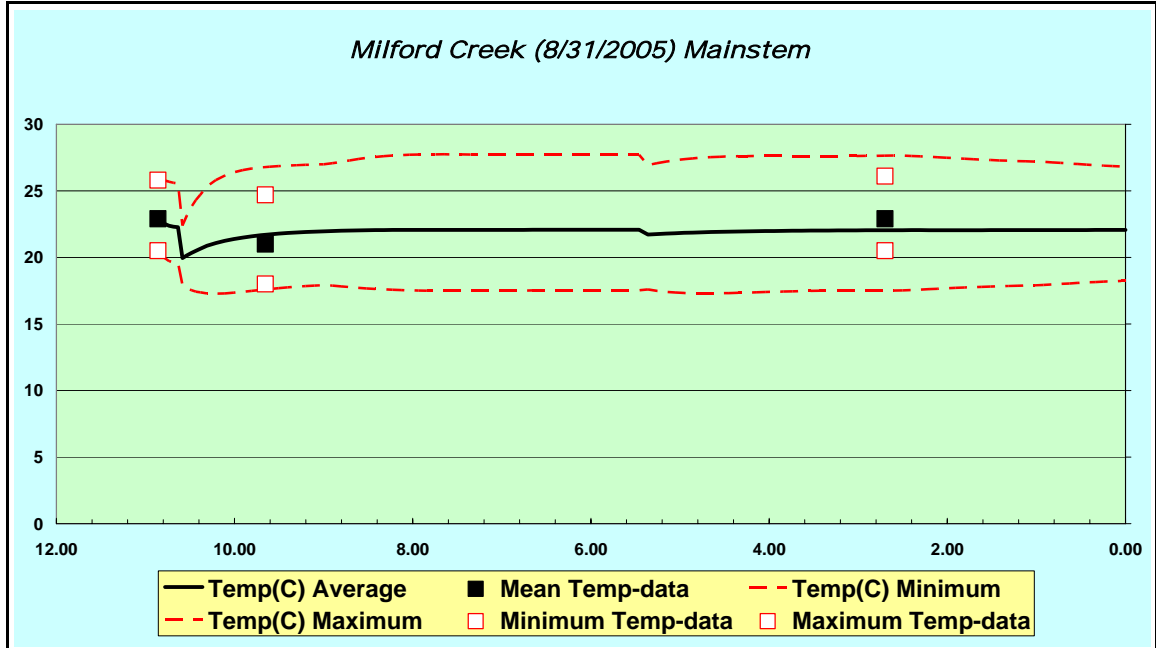


Figure D3. Model performance for longitudinal stream temperature.

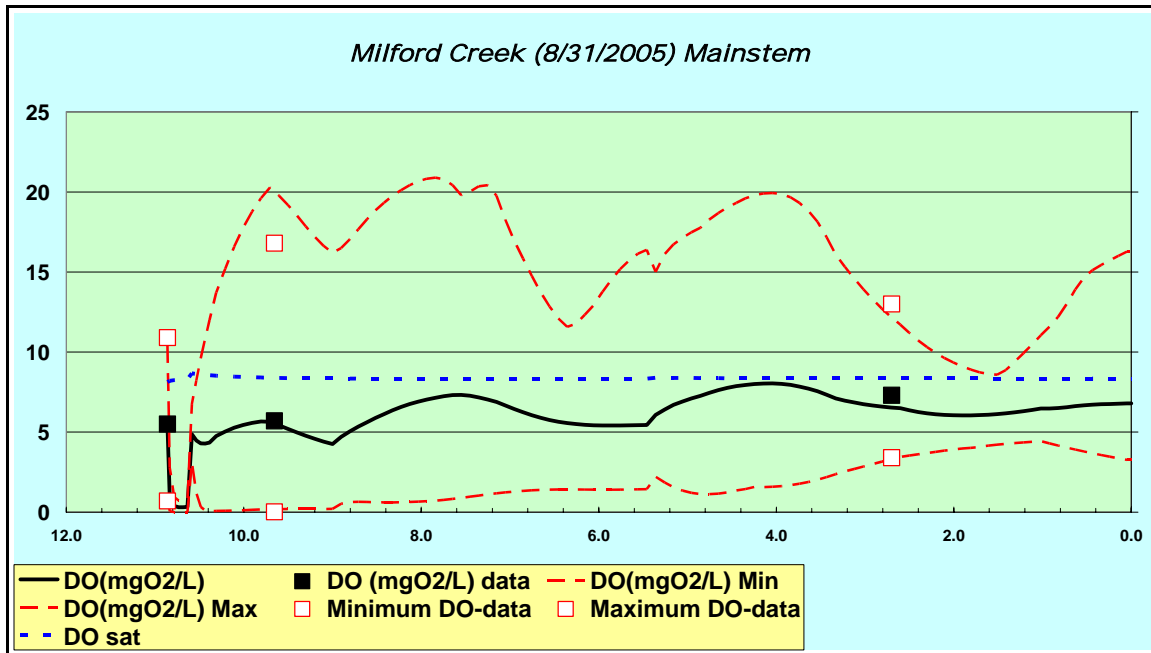


Figure D4. Model performance for longitudinal dissolved oxygen.

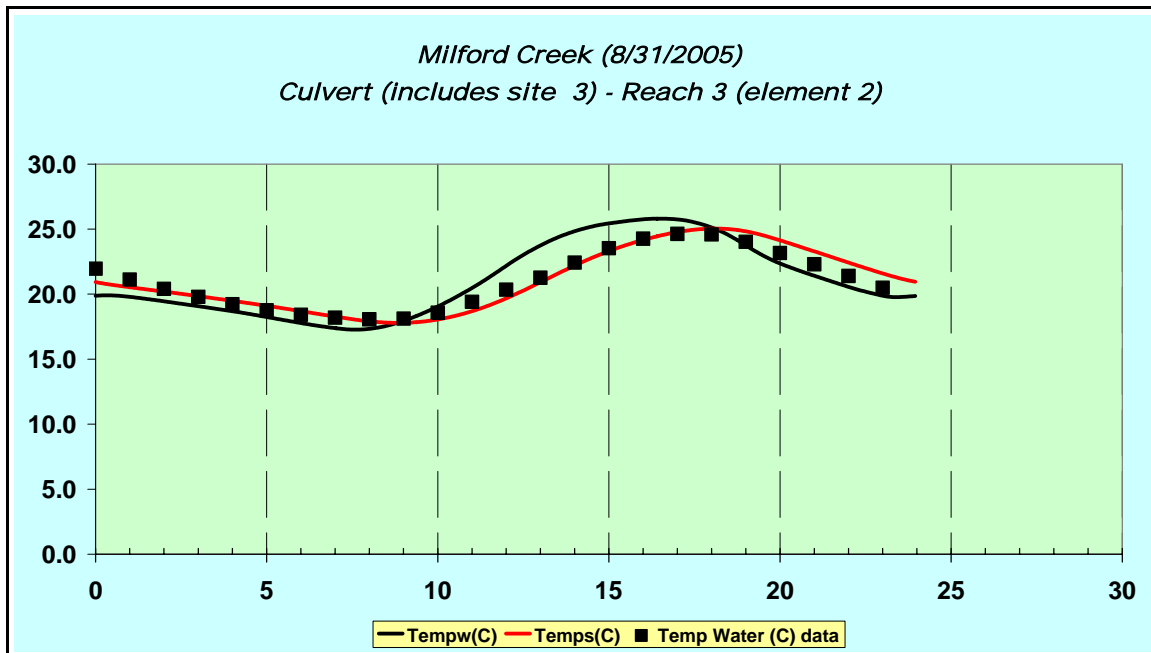


Figure D5. Model performance for diel stream temperature.

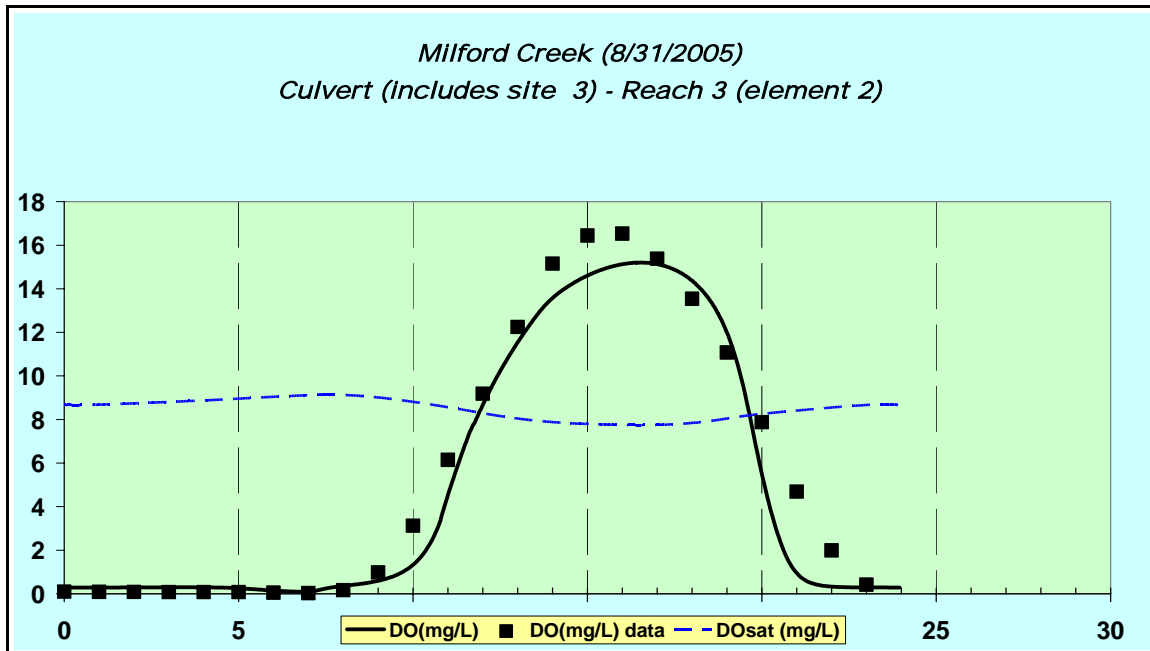


Figure D6. Model performance for diurnal (24-hour) dissolved oxygen.

*Results.* Following the calibration, a series of model runs were analyzed to determine the effects of alternative phosphorus wasteload scenarios on algal growth and dissolved oxygen. Prior to that, however, a determination of the baseline stream conditions was made by “removing” the wastewater treatment plant as a source of inflow to the stream. Figures D7 and D8 show the longitudinal and diurnal results for this analysis.

Under the current conditions (wastewater total phosphorus = 3.94 mg/l), model results show that dissolved oxygen criteria are not met in the downstream segment until stream kilometer 1.81 (distance from mouth). However, in a hypothetical scenario in which the wastewater treatment plant is eliminated, stream dissolved oxygen levels are able to meet water quality standards throughout the entire downstream segment of Milford Creek and the lower 53% of length of the upstream segment (up to km 8.23). This result reflects the impact of the dissolved plant-available phosphorus load from the WWTP and its subsequent effect on stream dissolved oxygen.

Table D3 shows the alternative total phosphorus wasteload scenarios that were analyzed and the percent of stream length meeting water quality standards following each model run. Reductions in phosphorus continually increase downstream oxygen levels until 0.15 mg/l, where the percent of stream length in compliance is maximized. Below 0.15 mg/l, algal growth is suppressed to a point where photosynthesis is limited and oxygen levels suffer. At 0.5 mg/l, the entire downstream segment is in compliance with dissolved oxygen standards.

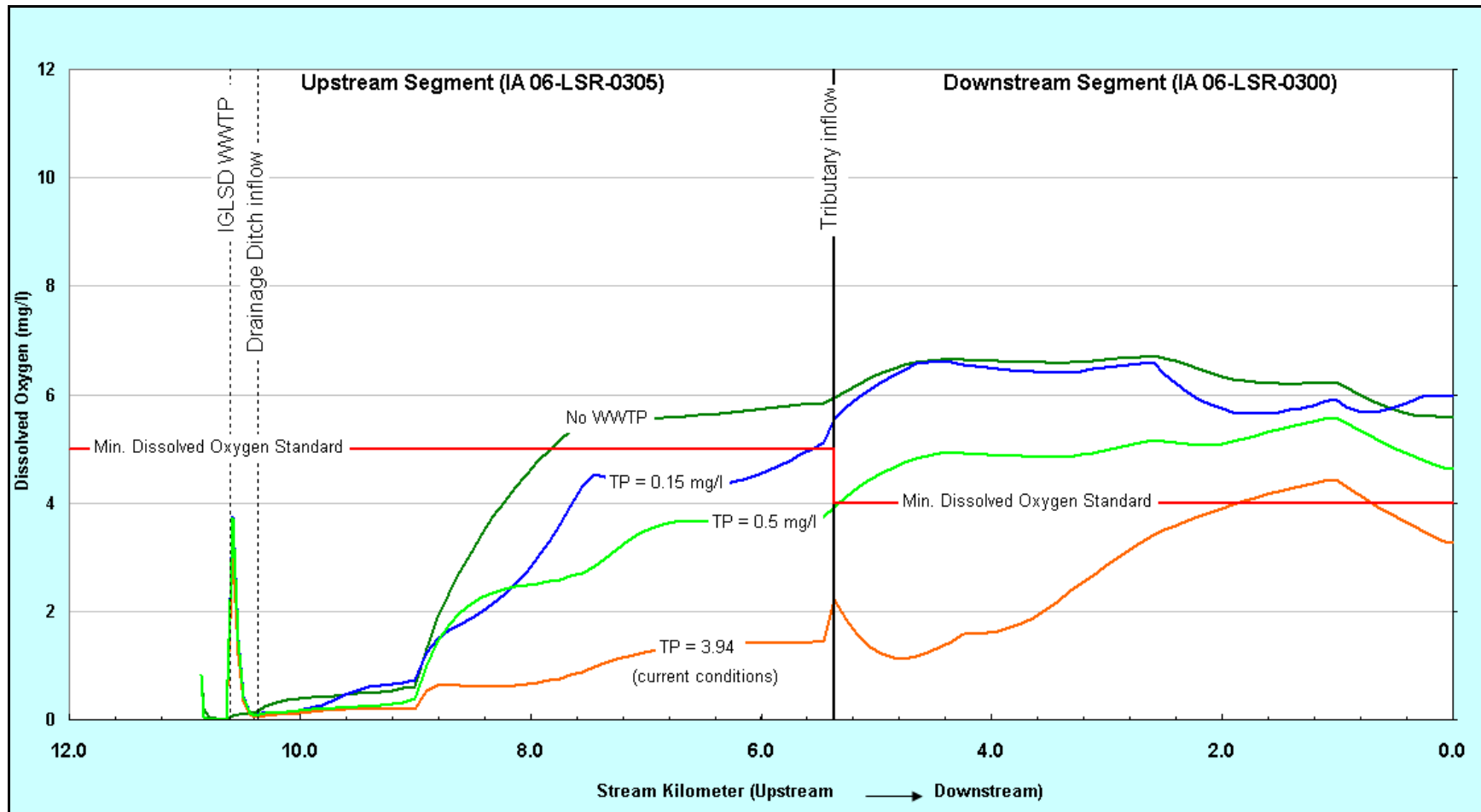


Figure D7. Qual2K modeling results: effect of alternative wastewater total phosphorus limits on downstream dissolved oxygen. Dissolved oxygen standard reflects current designated uses which are subject to change for upstream segment.

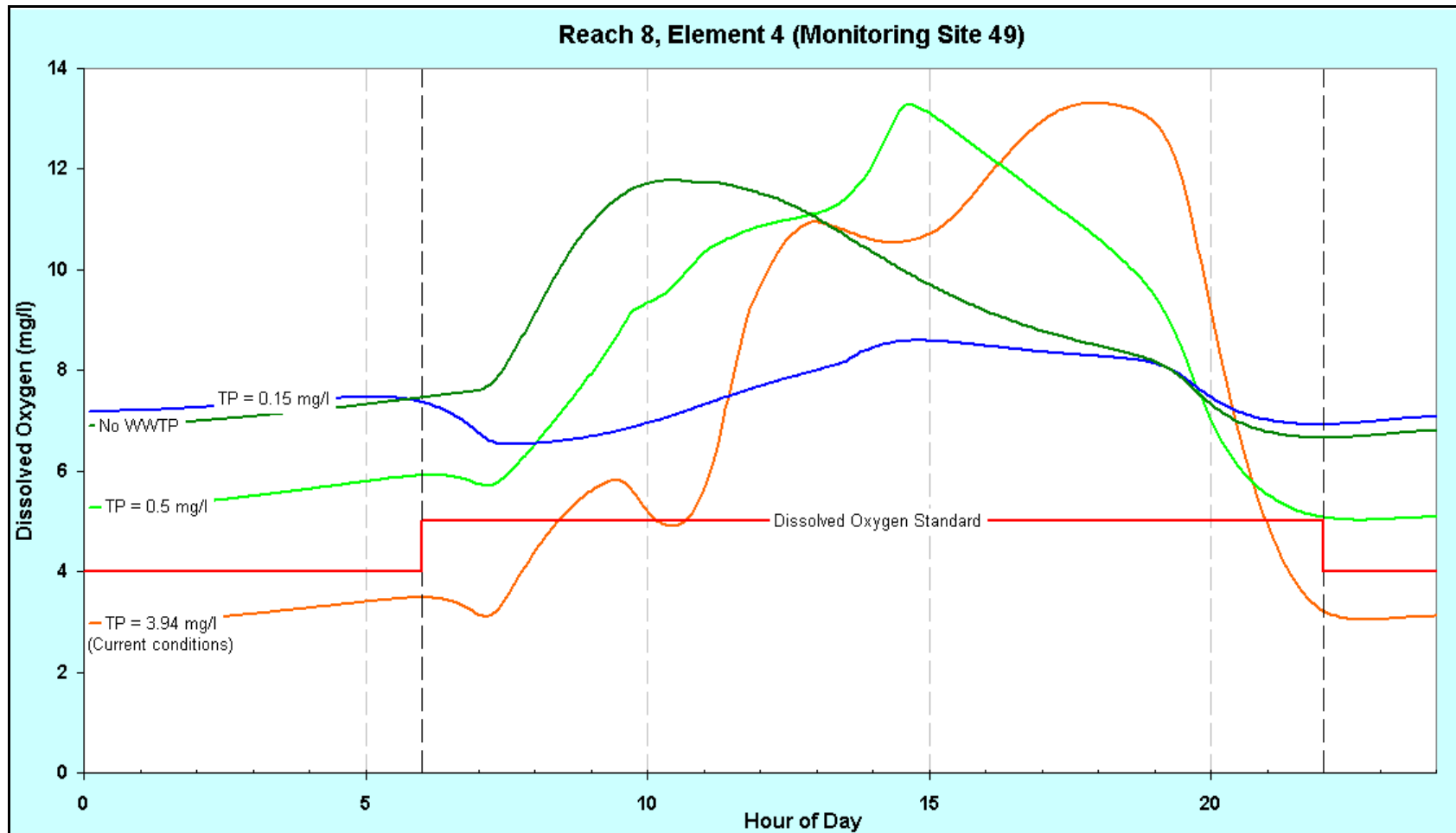


Figure D8. Qual2K modeling results: effect of alternative wastewater total phosphorus limits on 24-hour dissolved oxygen levels at monitoring Site #49.

**Table D3. Full summary of Qual2K modeling analysis.**

Total phosphorus concentration in wastewater effluent under critical conditions	Reduction needed	% Stream length meeting dissolved oxygen standard in UPSTREAM SEGMENT	% Stream length meeting dissolved oxygen standard in DOWNSTREAM SEGMENT
No WWTP	N/A	53.4%	100%
3.94 mg/l (current conditions)	0%	0%	22%
1.00 mg/l	75%	0%	30%
0.750 mg/l	81%	0%	60%
0.500 mg/l	87%	0%	100%
0.250 mg/l	94%	22.8%	100%
0.175 mg/l	96%	31.8%	100%
0.150 mg/l	96%	39.3%	100%
0.125 mg/l	97%	35.6%	100%
0.100 mg/l	97%	31.9%	100%
0.010 mg/l	99.7%	15.6%	100%

0.500 mg/l represents the first breakpoint, where the entire downstream segment attains dissolved oxygen standards.

0.150 represents the second breakpoint, where the percent of total stream length meeting standards is optimized.

*TMDL, WLA, and LA determination.* The steady-state or low flow TMDL is designed to protect the stream during the worst possible environmental conditions. For this project, it was determined by independently defining the WLA and LA under these conditions using available information and then summing them for a total load capacity.

For the WLA, the critical total phosphorus target was determined using the modeling results from Table D3 above. The percent stream length meeting WQS is maximized when the TP concentration from the IGLSD facility is at 0.150 mg/l; however, not even under baseline conditions (with no WWTP) can the upstream segment of Milford Creek meet dissolved oxygen standards during critical stream flows. This is due to the flow alteration imposed on the stream by the Lower Gar Lake dam and limiting physical conditions such as width, shallowness, and low gradient. Regulations and/or wasteload reductions imposed upon the IGLSD WWTP alone can not solve the impairment in the upstream segment. For that, it will take reductions in long term nonpoint source loading and/or alternative management strategies discussed in Chapter 4. Therefore, a target concentration of 0.500 mg/l total phosphorus in wastewater effluent was deemed appropriate to ensure that there would be no negative impact on the downstream segment.

The minimum daily flow value recorded at the IGLSD WWTP between the months of June through October (during which time critical environmental conditions apply) was used to calculate the critical condition WLA. This value, 1.645 MGD, was measured on 10/13/2000. Using this flow value and a target concentration of 0.5 mg/l, the critical condition WLA for Milford Creek is 6.9 lbs/day total phosphorus. To define the high

flow daily maximum wasteload, 42.8 lbs/day, the plant's maximum wet-weather flow (10.22 mgd as specified in the 2007 construction permit) was used. The long term annual average wasteload allocation of 6,408 lbs/year on average was determined using daily AWW and ADW phosphorus wasteload allocations assuming four months per year of ADW days and eight months per year AWW days.

The nonpoint source load allocation was developed using monitoring data collected from the storm drainage ditch and tributary sites in 2005. The inflows and TP concentrations from these sources were used to confirm that, during critical conditions, very little phosphorus is delivered from nonpoint source areas. The sum of these loads, including dry atmospheric deposition, is 0.1 lbs/day.

The high flow condition nonpoint source load allocation was determined by estimating and summing the estimated loads from Lower Gar Lake and the immediate watershed to Milford Creek at a concentration of 0.5 mg/l. The Stenback and Crumpton (2006) study was used to determine the maximum flow rate from Lower Gar Lake between 1999-2005 (506.9 cfs), and the Rational Method was used to determine the maximum inflow from the watershed for a 2-year, 24-hour rain event (73 cfs). At 0.5 mg/l, these loads equaled 1,376.6 lbs/day and 197 lbs/day respectively, or 1,607.4 lbs/day total.

The long term LA was set arbitrarily by equating it to the phosphorus reductions called for in the 2003 Lower Gar Lake TMDL report, i.e. 50%. This is based on the assumption that a 50% reduction in phosphorus loading into Lower Gar Lake will equate to a similar reduction in phosphorus export from the lake to Milford Creek, along with a 50% reduction from direct watershed sources being needed.

*Summary.* The model shows that under critical stream conditions, reductions in point source phosphorus loading can make a direct impact on downstream dissolved oxygen levels in Milford Creek. However, flow alterations and physical limitations in the upstream segment preclude the attainment of WQS through the implementation of a point source WLA alone. There, additional management strategies may be needed in addition to both point source and nonpoint source phosphorus reductions. Such strategies might include riparian tree shading, aquatic plant biomass harvesting, and channel deepening.

### **Estimation of nonpoint source phosphorus loading**

Nonpoint sources of phosphorus to Milford Creek were classified as follows: 1. Loads from the upper Iowa Great Lakes watershed, delivered from Lower Gar Lake during high flow periods; 2. Surface runoff loads estimated separately as dissolved and sediment-attached phosphorus; and 3. Natural background loading from atmospheric deposition.

To estimate loading from the upper Iowa Great Lakes watershed, information from an ISU study was utilized (Stenback and Crumpton, 2006). This study consisted of developing a mass-balance budget for total phosphorus and water movement throughout the Iowa Great Lakes, specifically for Lower Gar Lake. Results included exports of water and phosphorus to Milford Creek for the years 1999-2005 (Table D4), which is felt to cover a sufficient statistical range for characterizing phosphorus and flow exports

based on annual precipitation. The total annual rainfall received between the years 1999-2005 ranged from the 18<sup>th</sup> percentile (20.4" in 2003) to the 95<sup>th</sup> percentile (37.7" in 2004) of long term data records (IEM, 2007).

A supplement to this study was done to compare the outputs from Lower Gar Lake to that of the IGLSD wastewater treatment plant. Results of this supplemental work are included in Appendix E.

To estimate event-driven nonpoint source loading, procedures from EUTROMOD's loading function were used (Reckhow, 1992). This method is commonly utilized in Iowa and in other states for estimating long term nonpoint source loadings of phosphorus. It estimates watershed total phosphorus loading as two separate fractions, dissolved and sediment-attached. The dissolved fraction is estimated by multiplying volumetric surface runoff estimates from unique land use categories by event mean concentrations (EMC's) also unique to different land use categories (Table D5).

The EUTROMOD method for estimating sediment-attached phosphorus is similar to the Iowa Phosphorus Index (Mallarino et al., 2005). Sheet and rill erosion is estimated using the Revised Universal Soil Loss Equation (RUSLE), and delivery to the stream is estimated using the Iowa NRCS Erosion and Sediment Delivery procedure. Based on watershed size and landform region, the sediment delivery ratio at the mouth of Milford Creek is 4.85%, meaning this is the fraction of gross field erosion which actually reaches the stream's mouth. The mass of soil loss is then multiplied by a soil phosphorus concentration and enrichment ratio according to land use type to get total sediment-attached phosphorus delivery.

Atmospheric deposition, or background loading, was estimated using measured rates of dry and wet total phosphorus deposition in the Iowa Great Lakes region. Stenback and Crumpton (2006) measured dryfall rates of TP to be 0.049 lbs/day, while wetfall TP concentrations were 0.0493 mg/l on average. At 28.3 inches of rain per year, this equates to 12.2 lbs/year. Annual deposition rates were multiplied by the surface area of the creek as determined from aerial photographs.

Table D4. Model lake total phosphorus (TP) budget summary for Lower Gar Lake (metric tons, (% of Total Inputs)) (taken from Stenback and Crumpton, 2006).

Nutrient	Inputs					Outputs			Annual Water Column Storage*	Nutrient Mass In Lake Water Column at End of Year
	Rain	Dry Dep.	Watershed	Adjacent Lake (Minn. L)	Sediment to Lake Flux	Adjacent Lake (Minn. L)	Lake to Sediment Flux	Milford Creek		
1999	0.02 (<1)	0.04 (1)	1.16 (30)	1.43 (36)	1.27 (33)			3.93 (101)	-0.02 (-1)	0.11
2000	0.02 (5)	0.04 (11)	0.25 (70)		0.05 (14)	0.39 (109)		0.00 (0)	-0.03 (-9)	0.07
2001	0.02 (1)	0.04 (2)	2.08 (82)	0.08 (3)	0.33 (13)			2.51 (98)	0.04 (2)	0.12
2002	0.02 (1)	0.04 (3)	0.39 (31)		0.80 (64)	1.24 (100)		0.01 (1)	-0.01 (-1)	0.11
2003	0.01 (2)	0.04 (7)	0.52 (88)		0.02 (3)	0.59 (99)		0.00 (0)	0.01 (1)	0.11
2004	0.03 (1)	0.04 (2)	1.40 (55)		1.09 (43)	0.13 (5)		2.35 (92)	0.08 (3)	0.20
2005‡	0.02 (1)	0.02 (1)	1.00 (57)	0.70 (40)			0.13 (7)	1.57 (90)	0.04 (2)	0.06

\* End of year minus beginning of year mass of TP in the lake water column.

† Two outlier TP concentrations of >0.5 mg/L (one in 2000 and another in 2004) were set to 0.2 mg/L to better match temporally adjacent measurements.

‡ 2005 results are from the more detailed study and are shown here for comparison.

**Table D5. Input values for EUTROMOD Loading Function procedure.**

2002 Land Cover	Runoff Coefficient	Dissolved TP in runoff (mg/l)	Soil P Concentration (mg/kg)
Open water	1.00	0.00	0
Wetland	0.90	0.00	0
Wet forest	0.15	0.01	500
Coniferous forest	0.15	0.01	500
Deciduous forest	0.15	0.01	500
Ungrazed grasslands	0.23	0.10	500
Grazed grasslands	0.25	0.25	500
CRP	0.23	0.10	500
Alfalfa	0.23	0.15	500
Corn	0.26	0.26	575
Soybeans	0.26	0.26	575
Other Agriculture	0.26	0.26	575
Roads	0.86	0.12	500
Commercial/Industrial areas	0.61	0.38	500
Residential areas	0.50	0.38	500
Barren	0.60	0.25	500

## **Appendix D --- Images and Maps**



Figure E1. Photo of Milford Creek in July 2004 taken by IDNR.



Figure E2. Photo of Milford Creek in July 2005 (courtesy of Dan Eckert, Dickinson County Engineer).



Figure E3. Photos of fish kill in 2006 below Lower Gar Lake dam (courtesy of Glen Petersen, IGLSD superintendent).



Figure E4. Photo of fish kill in 2007 below Lower Gar Lake dam (courtesy of Glen Petersen, IGLSD superintendent).

## **Appendix E --- Supplemental Study on IGLSD Phosphorus Output (Stenback and Crumpton, 2006)**

### **Brief Analysis of IGLSD and Lower Gar Lake TP Loads**

Discharge from Lower Gar Lake was estimated on the basis of the USGS daily lake elevation data at West Okoboji Lake and a discharge equation based on the Lower Gar outflow structure dimensions and water head overtopping the spillway as described by Crumpton and Stenback, 2006.

1. The IGLSD discharge is generally a small fraction of the Lower Gar Lake discharge to Milford Creek when water is flowing. However, there are periods lasting from months to over a year when Lower Gar Lake discharge is zero. During these periods of no flow, the IGLSD (plus any other sources not accounted for here) makes up the entire flow to Milford Creek just below Lower Gar Lake (Figure 1). The difference between IGLSD and Lower Gar discharge TP load (Figure 5) is less extreme because the IGLSD TP concentrations are about one order of magnitude or more greater than Lower Gar Lake water column TP concentrations.
2. There is a correlation between IGLSD discharge and rainfall measured at the NOAA weather station at Milford, IA (Figure 2) with peak IGLSD flows generally occurring during the rainy period in late spring and summer.
3. IGLSD TP concentration is inversely related to IGLSD discharge (Figure 3). This observation in conjunction with item 2 suggests that during wet periods the IGLSD system may be receiving flow from leakage, storm sewers, sump pumps, etc. This can have serious consequences on estimation of TP loads based on the product of average TP concentration and discharge, as described below.
4. The product of discharge and concentration (adjusted for appropriate unit conversions) gives load. The load based on the Feb. 2005 to June 2006 IGLSD data shows a pattern that may be approximated reasonably well using an annually cyclical relationship ( $R^2 = 0.72$ , Figure 4; note that a slightly more complicated model that includes discharge together with the cyclical terms provides a minor improvement having  $R^2 = 0.77$ ). This cyclical pattern may be expected for a population that follows an annual cyclical pattern. To the extent that the local population dynamics are similar from year to year, the cyclical approximation observed for the Feb. 2005 to June 2006 time period may provide a reasonable estimate of typical TP loading from the IGLSD for other years.
5. IGLSD TP load calculated as the product of average TP concentration and daily discharge will not accurately estimate the daily TP load. For the Feb 2005 to June 2006 IGLSD data, daily loads estimated this way are overestimated when flow is high and underestimated during the peak load months of July to September (Figure 4).
6. Daily TP load discharged from Lower Gar is difficult to estimate accurately because there are generally less than seven or eight lake water samples available (to us) per year

and few, if any, were collected during the late fall, winter, or early spring. Lower Gar sample data show lake water column TP concentrations ranging between 0.05 to near 0.3 mg/L during 1999 to 2004, with an estimated flow-weighted average (FWA) of 0.155 mg/L (based on Crumpton and Stenback 2006 nutrient budget modeling). The product of this FWA concentration and daily discharge from Lower Gar gives the estimated TP discharge from Lower Gar to Milford Creek illustrated in Figure 5.

The IGSLD cyclical model and the product of IGLSD discharge and average TP concentration show a similar overall pattern, but the average TP concentration times discharge may severely overestimate load during time periods when the IGLSD discharge is high and may underestimate TP load during other time periods (Figure 5).

#### Reference

Crumpton, W.G. and Stenback, G.A., 2006, "Estimating Phosphorus Loads for Shallow Lakes: Case Study for Lower Gar Lake, Iowa", Final report submitted to the Iowa Department of Natural Resources, August 2006.

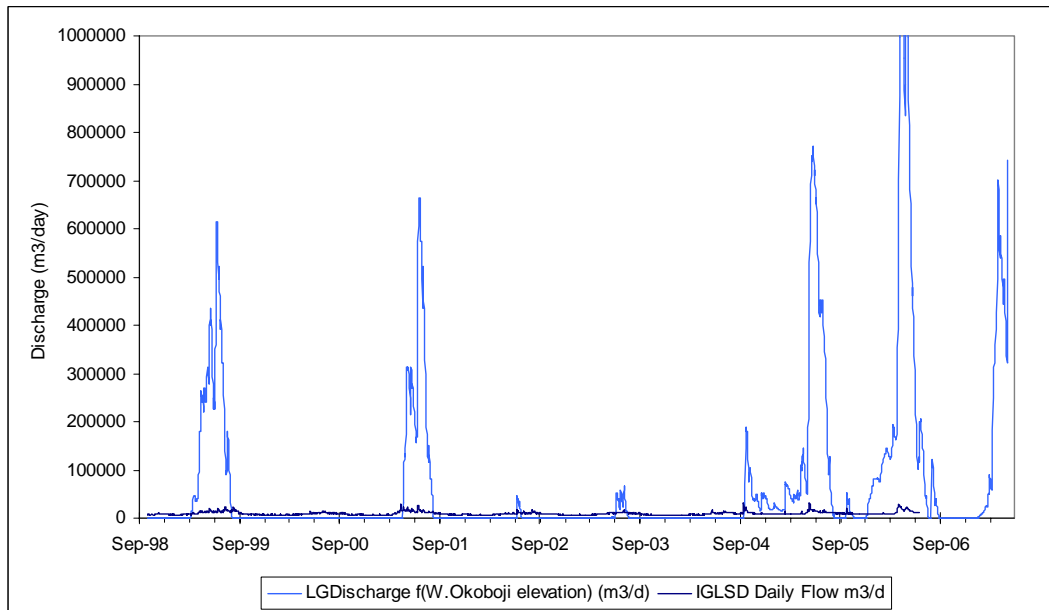


Figure 1. IGLSD discharge (source: Joe Herring, IDNR, 5/8/2007 email) and estimated Lower Gar discharge to Milford Creek based USGS West Okoboji Lake daily surface elevation and a weir discharge equation based on the Lower Gar Lake outflow structure dimensions.

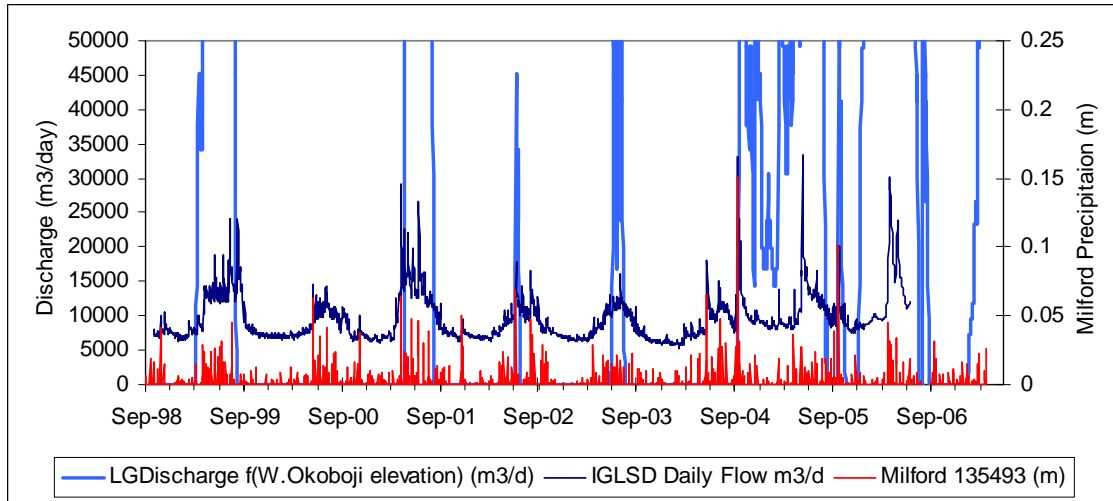


Figure 2. IGLSD discharge, Lower Gar discharge (mostly off-scale) and precipitation at Milford, IA from the NOAA/National Climate Data Center station 135493.

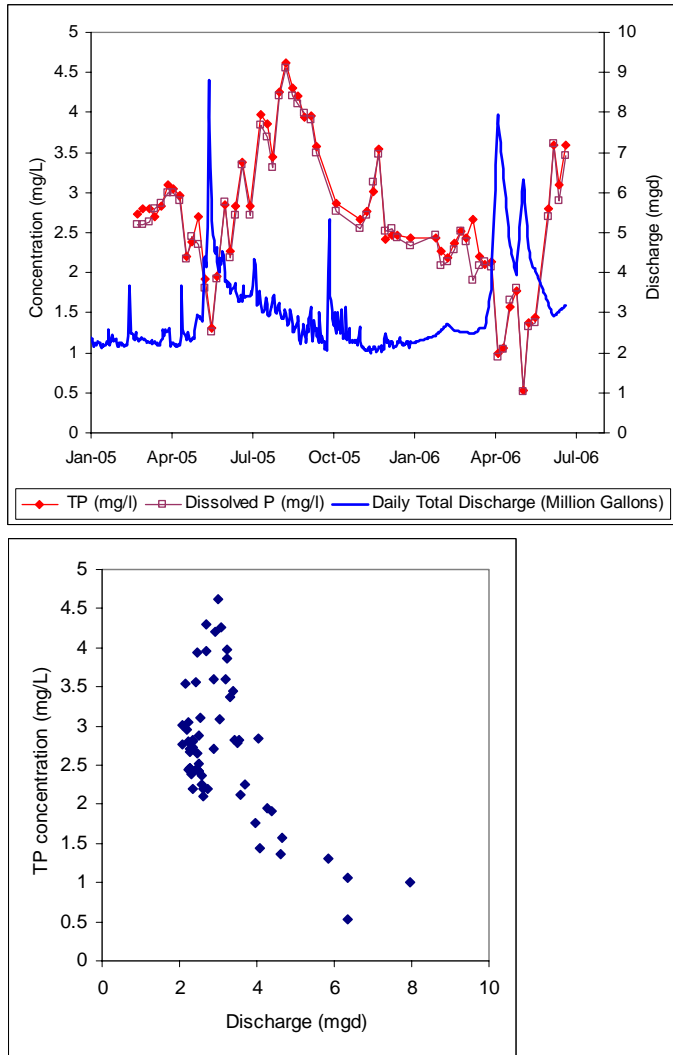


Figure 3. IGLSD TP (and dissolved P from Joe Herring via e-mail) concentration tends to decline as flow increases (left panel) resulting in an inverse relationship to IGLSD discharge (right panel).

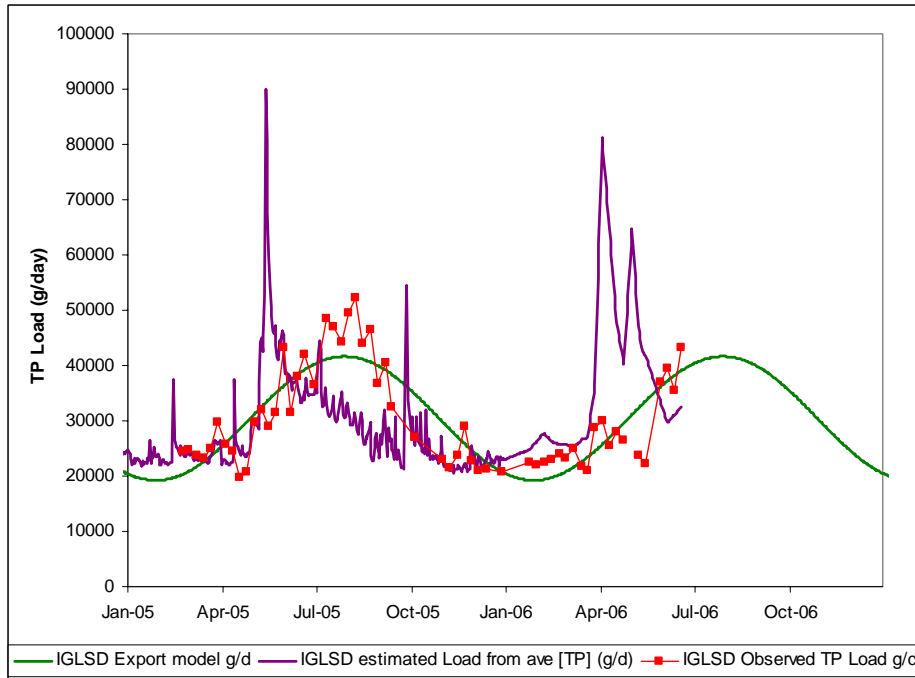


Figure 4. Feb. 2005 to June 2006 IGLSD TP load follows a pattern that is approximately cyclic with an annual period ( $R^2 = 0.72$ ). TP load calculated as the product of average TP concentration and discharge does not accurately estimate the daily loads as illustrated by load overestimation when flow is high, generally April and May, and load underestimation during July to September.

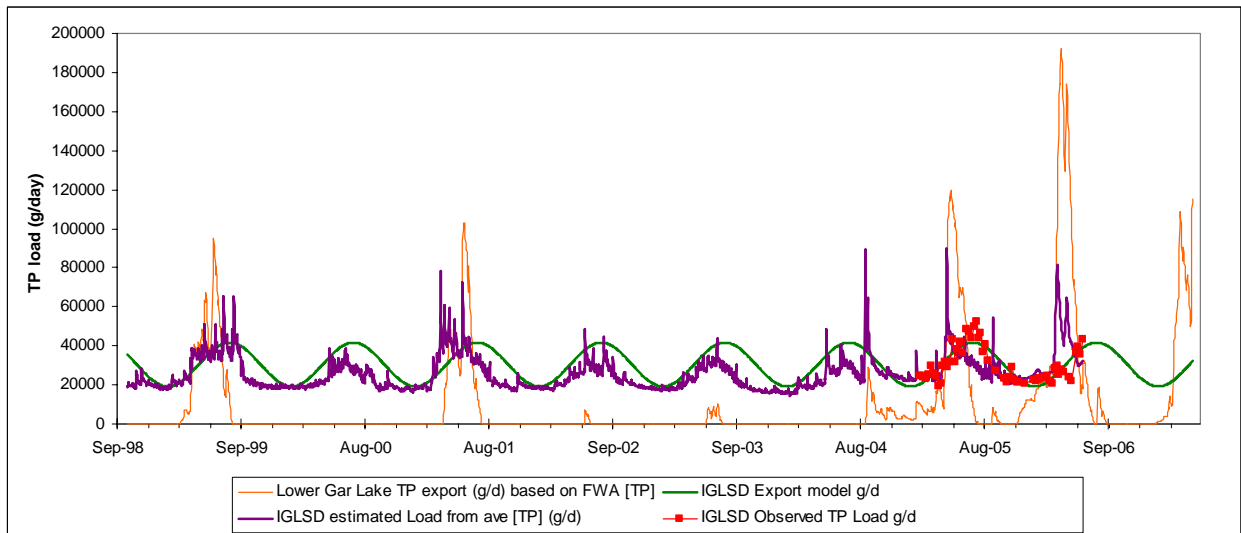


Figure 5. Estimated TP load discharged from Lower Gar Lake (based on model discharge and FWA TP concentration), IGLSD cyclical model extended backward and forward in time, and the product of IGLSD discharge and average TP concentration.

## **Appendix F --- Public Comments**

This space reserved for comments following 30-day public input period.

## Appendix G --- Stressor Identification

The goal of this stressor identification (SI) document is to determine the cause of the biological impairment on Milford Creek in Dickinson County. This waterbody is included on the 303(d) list of impaired waters and is scheduled for TMDL development in 2004.

Data available for Milford Creek includes two biological samples collected in 2001, water chemistry data from 2001, 2002 and 2004, and data from the Iowa Great Lakes Sanitary District. The data were analyzed and the SI was completed by three members of the TMDL and Water Quality Assessment Section of the DNR. The SI follows steps A-G outlined in the IDNR (2004) procedures document, which was developed from U.S. EPA (2000) guidelines.

### A. Describe the Impairment

#### 1. *What effect is observed?*

Early suggestions of impairment were made in October 1990; comments suggest that the poor composition of the fish community may be related to the predominance of wastewater effluent in the creek. The impairment was also noted as low habitat diversity and low numbers of fish during seining in 1994.

Field sheets from October 1995 DNR stream use assessments show that the fish community in Milford Creek lacks several of the expected species/genera for Class B(LR) streams in this region. The survey showed a diverse fish community of 19 species from 8 families; however, the community was dominated by lake-dwelling species such as northern pike, yellow bass, largemouth bass, crappie, yellow perch, and walleye. While minnows (family Cyprinidae) typically dominate Iowa's Class B(LR) streams, the only cyprinid species sampled from Milford Creek was carp. Only 4 of the 11 fish species expected for Class B(LR) streams in the Des Moines Lobe (47b) sub-ecoregion were present, suggesting an impairment.

Data used to develop the 2002 305(b) assessment of the impairment include bioassessment results from September 2001 and monthly monitoring conducted by UHL from March through November 2001. The Fish Index of Biotic Integrity (FIBI) scores from September 2001 were 38 (fair) upstream and 50 (fair) downstream; the Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) scores were 15 (poor) and 44 (fair). Results of chemical monitoring in the stream showed relatively good water quality. None of the 9 samples collected from March through November violated Class B(LR) water quality criteria for dissolved oxygen (minimum value = 5.7 mg/l), pH (range of 7.9 to 8.9 units), or ammonia-nitrogen (maximum value = 0.40 mg/l). This monitoring, however, showed some very high levels of total phosphorus in Milford Creek. The mean, median, and maximum total phosphorus levels for the TMDL monitoring at the lower Milford Creek sampling site in 2001 were 1.0, 0.7, and 2.2 mg/l, respectively. Sample values for total phosphorus in the September, October, and November samples were 2.2, 2.1, and 1.1 mg/l, respectively. Compared to levels measured at regional reference stream sites and ambient monitoring sites,

these atypically high levels of total phosphorus in Milford Creek suggest a potential problem with organic enrichment.

2. *How was the effect determined?*

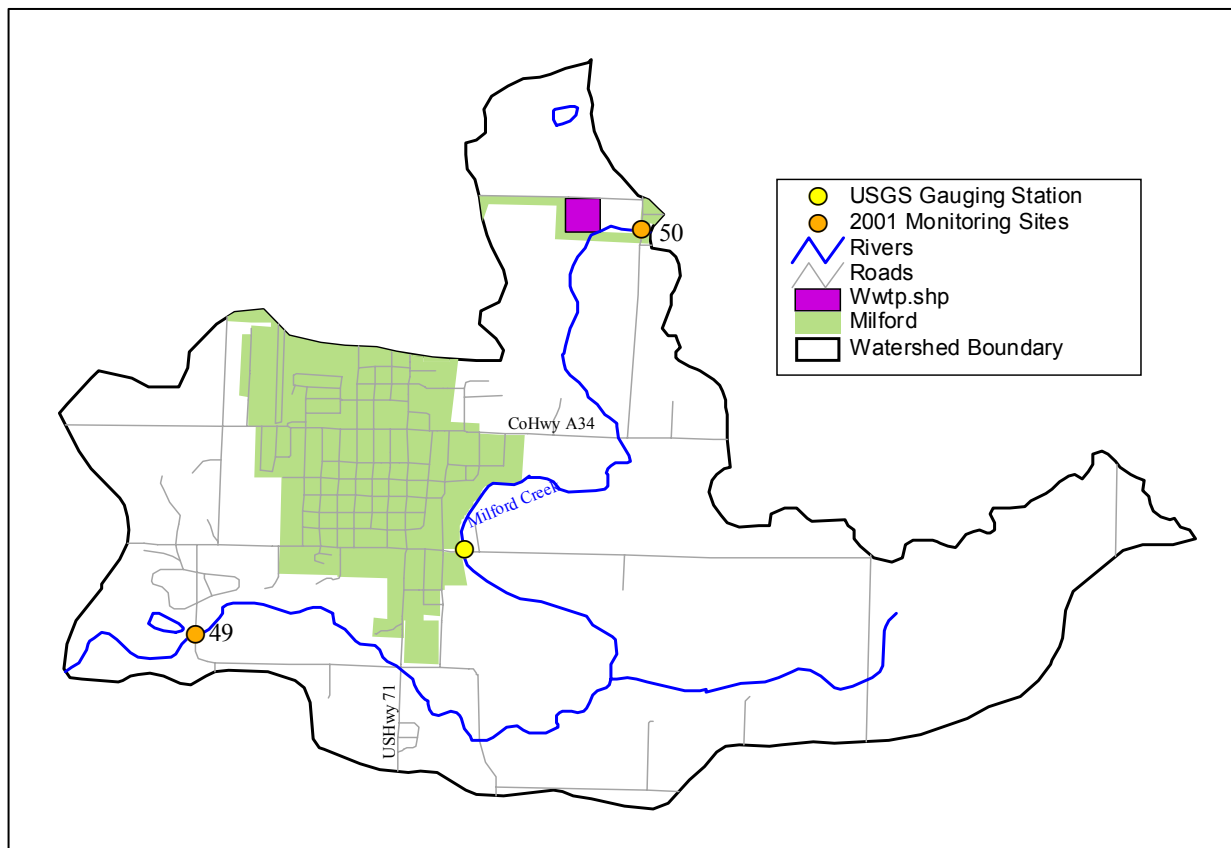
Biotic index scores were compared to reference sites in the Des Moines Lobe ecoregion. According to Table 1 of Attachment 2 in the “Methodology for developing Iowa’s 2002 Section 303(d) list of Impaired Waters,” BMIBI scores of 63 or higher are considered ‘supporting’ for benthic macroinvertebrates. FIBI scores of 55 or higher in riffle habitat and 32 or higher in non-riffle habitat are classified as ‘supporting’ for fish. While the FIBI scores of 38 and 50 are considered passing, the BMIBI scores of 15 and 44 are far below the expected level.

It is important to note that, while the downstream half of Milford Creek is a designated Class B(LR) water body, the upstream half of the stream is designated as General Use. Because the IBI guidelines for listing a water as impaired were developed for Class B streams, the IBI guidelines assessment criteria not be realistic for the upstream site.

3. *Where is the impairment?*

- a. Geographic (Spatial) Extent. The impairment is along the full 6.2 miles of Milford Creek in Dickinson County. The 5,000 acres of direct drain watershed includes the town of Milford, an auto junkyard, row crop agriculture, livestock, spoils piles from gravel mining, and a wastewater treatment plant (see map in Figure 1). Milford Creek is at times also fed by flow from Lower Gar Lake. Through Lower Gar, it is possible that Milford Creek receives water from all of the Iowa Great Lakes, which have a watershed area of 69,000 acres (108 square miles).
- b. Temporality. Insufficient samples have been taken to quantify seasonal or annual variation.
- c. Chronology. The impairment was first documented in a 1990 stream use assessment. The impairment was more quantitatively identified in 2001 with full bioassessments at two sites.
- d. Severity. The impairment is considered moderately severe. Spatially, the impairment appears to span all 6.2 miles of the listed ‘impaired’ segment of Milford Creek.
- e. Evidence. Evidence for the impairment includes two biological samples, collected at two sites, using multiple indicators. The assessment approach compares Milford Creek biological index levels to regional reference site index levels. These reference sites represent desirable and attainable biological conditions for streams located in the same ecoregion.
- f. Confidence. Because the two sampling locations were at either end of the ‘impaired’ stretch of Milford Creek, we are fairly confident that the impairment is represented throughout the listed segment.

Figure 1. Milford Creek and its watershed, including sampling locations and the wastewater treatment plant.



## B. List Possible Causes

### 1. List ALL possible stressors for the waterbody

Table 1 lists the possible causes of impairment that were identified by the SI team of investigators. GIS maps depicting natural and anthropogenic features of the Milford Creek watershed were examined. The presence or absence of potential sources of pollution or habitat alteration were noted. A master list of impairment causes and sources based on Section 305(b) assessment methodology was reviewed to ensure that all possible causes and sources were initially considered. A visit to the watershed provided additional insight into landscape, land use, and stream development factors that might influence the biological, chemical, and physical characteristics of Milford Creek. Following a brief review of the GIS coverages, watershed observations and water quality data, a numeric rating was assigned to each potential cause.

Table 1. Potential stressors in Milford Creek. A rating of 1 signifies high potential impact, 2 signifies moderate potential impact and 3 signifies low potential impact.

Possible Causes	Rating
<ul style="list-style-type: none"> <li>Habitat Alterations <ul style="list-style-type: none"> <li>Barriers to movement</li> <li>Riparian vegetation loss</li> <li>Algal growth</li> </ul> </li> <li>Channelization</li> <li>Siltation</li> </ul>	1
<ul style="list-style-type: none"> <li>Nutrients <ul style="list-style-type: none"> <li>Phosphorus</li> <li>Nitrogen <ul style="list-style-type: none"> <li>Nitrate + Nitrite</li> <li>Kjeldahl nitrogen</li> </ul> </li> <li>Total ammonia</li> </ul> </li> </ul>	1
<ul style="list-style-type: none"> <li>Physical and Chemical Traits of Water <ul style="list-style-type: none"> <li>Dissolved oxygen</li> <li>pH</li> </ul> </li> </ul>	1
<ul style="list-style-type: none"> <li>Other <ul style="list-style-type: none"> <li>Thermal Modification</li> </ul> </li> </ul>	2
<ul style="list-style-type: none"> <li>Exotic/Introduced/Undesirable Species <ul style="list-style-type: none"> <li>Predation</li> <li>Competition</li> <li>Excessive Macrophytes</li> </ul> </li> </ul>	2
<ul style="list-style-type: none"> <li>Physical and Chemical Traits of Water <ul style="list-style-type: none"> <li>Chlorophyll a</li> <li>Suspended solids</li> <li>TDS</li> <li>Turbidity</li> </ul> </li> </ul>	2
<ul style="list-style-type: none"> <li>Flow Alterations <ul style="list-style-type: none"> <li>Dams</li> <li>Pumping</li> <li>Tile flow</li> </ul> </li> </ul>	2
<ul style="list-style-type: none"> <li>Toxins <ul style="list-style-type: none"> <li>Metals <ul style="list-style-type: none"> <li>Arsenic</li> <li>Cadmium</li> <li>Chromium</li> <li>Copper</li> <li>Lead</li> <li>Mercury</li> <li>Selenium</li> <li>Zinc</li> <li>Other metal toxin</li> </ul> </li> <li>Non-Metals <ul style="list-style-type: none"> <li>Chlorine</li> <li>Cyanide</li> <li>Sulfur</li> <li>Unionized ammonia</li> <li>Priority organics</li> <li>Non-priority organics</li> <li>Other non-metal toxin</li> </ul> </li> </ul> </li> </ul>	2
<ul style="list-style-type: none"> <li>Habitat Alterations <ul style="list-style-type: none"> <li>Wetland loss</li> <li>Stream dewatering</li> </ul> </li> </ul>	3
<ul style="list-style-type: none"> <li>Pesticides/Herbicides <ul style="list-style-type: none"> <li>Pesticides <ul style="list-style-type: none"> <li>Atrazine</li> <li>Other</li> </ul> </li> <li>Herbicides</li> </ul> </li> </ul>	3
<ul style="list-style-type: none"> <li>Other <ul style="list-style-type: none"> <li>Oil/grease</li> <li>Noxious aquatic plants</li> <li>Depletion <ul style="list-style-type: none"> <li>Predation (Natural/Introduced)</li> </ul> </li> </ul> </li> </ul>	3

2. *Eliminate unlikely causes (document the reason for elimination)*

- Physical and Chemical Traits of Water
  - Salinity – No evidence of trait outside of normal range.
- Other
  - Depletion
    - Disease – Not known to exist within the watershed.
    - Harvest – Not known to exist within the watershed.
  - Radiation – Not known to exist within the watershed.

**C. Develop Conceptual Models**

1. *Link the cause(s) with the effect*
2. *Draw a visual model of the pathway(s) or mechanism(s) (e.g., box-and-arrow)*
3. *Determine possible interactions between various causes*

To accomplish objectives C1 to C3, flow charts have been developed for potential habitat issues (Figure 2) and for potential water quality sources (Figure 3) in Milford Creek.

**D. Analyze Evidence**

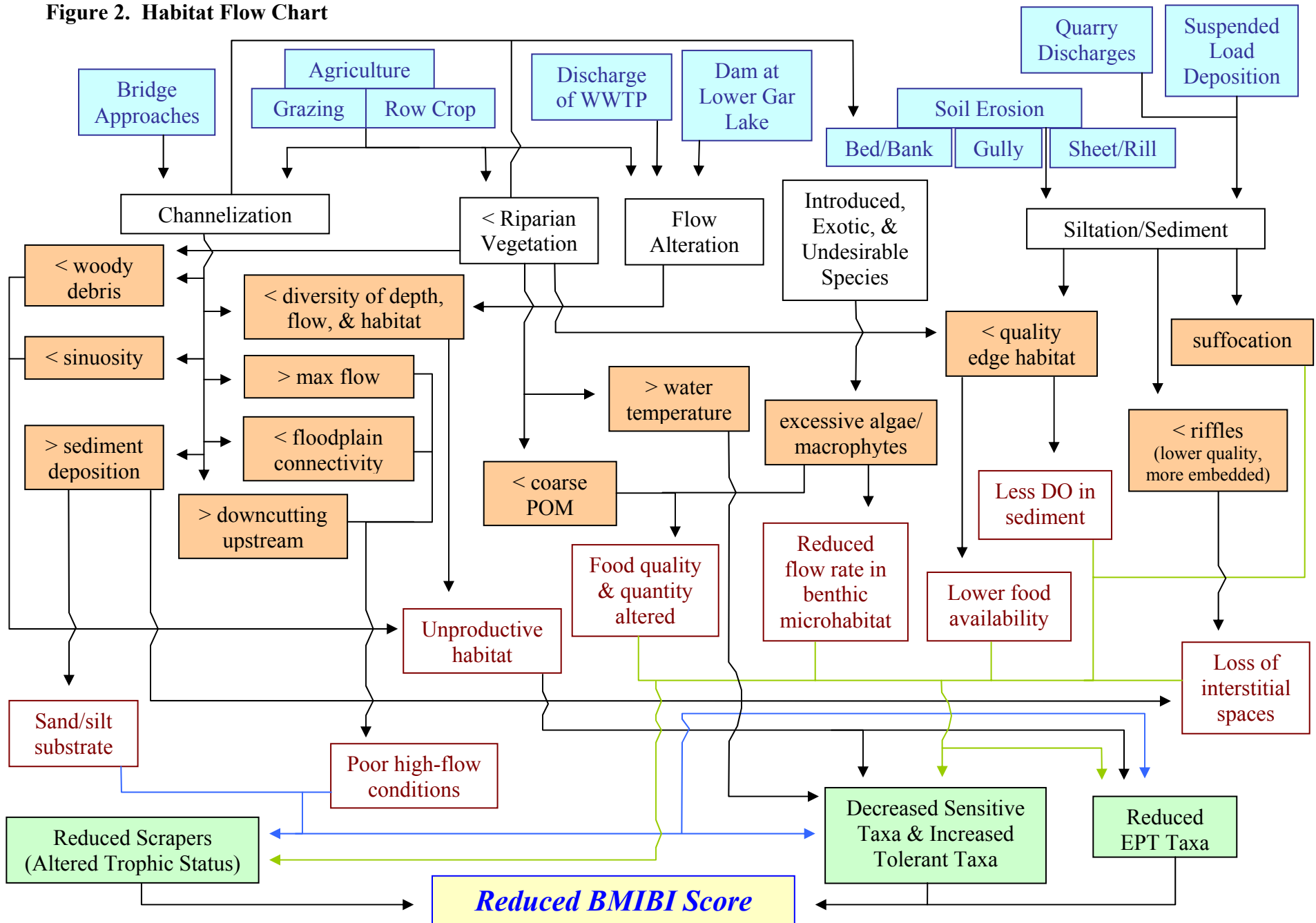
Summaries of the data and evidence used for this SI may be found in the Appendices. Contact the TMDL and Water Quality Assessment Section for additional information on available data/evidence and how they were used. The analysis of evidence was largely conducted in conjunction with Cause Characterization (E1).

**E. Characterize the Cause(s)**

1. *Analyze strength of evidence.*

Table 2 lists the results of the causal evidence analysis. For each possible cause, a rating was assigned to each of the evidence categories in the table's leftmost column. The last evidence category (xii) is for any remarks pertaining to evidence coherence. The bottom row is a sum of the individual ratings. The higher the rating for a particular stressor, the stronger the evidence that the stressor is a significant causal factor in the biological impairment.

**Figure 2. Habitat Flow Chart**



**Figure 3. Water Quality  
Flow Chart**

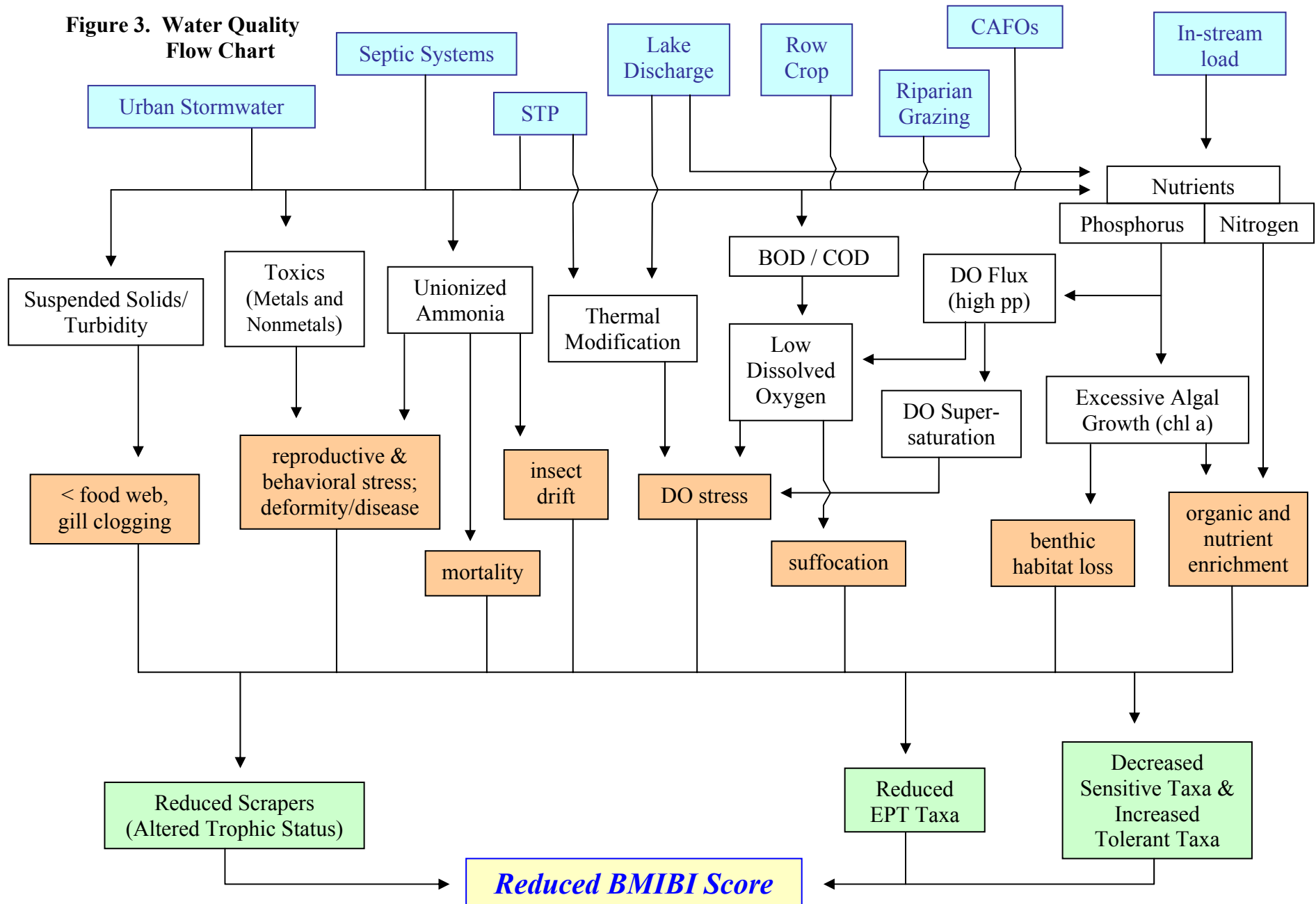


Table 2. Causal evidence analysis for Milford Creek.

	TSS/ Turbid	Toxins	Cl <sup>-</sup>	NH <sub>3</sub>	pH	Nutrients		DO	Thermal Modif- ication	Silt/ Sediment	Channel -ization	<Riparian Vegeta- tion	Flow Alter- ation	Algae/ Macro- phytes
						N	P							
i) co-occurrence	-	0	0	+	-	+	+	+	-	0	0	-	+	+
ii) temporality	0	0	0	0	0	0	0	0	0	0	0	0	0	0
iii) biological gradient	-	0	0	-	-	0	0	0	-	+	0	-	+	0
iv) exposure pathway	-	0	0	+	-	+	+	+	-	+	0	-	+	+
v) consistency of association	-	0	0	-	-	0	0	+	-	0	0	-	0	0
vi) experiment	0	0	0	0	0	0	0	0	0	0	0	0	0	0
vii) plausibility	0	0	0	0	0	+	+	+	0	+	0	0	0	+
viii) analogy	0	+	+	+	0	+	+	+	0	+	0	0	+	+
ix) specificity of cause	0	0	0	0	0	0	0	0	0	0	0	0	0	0
x) predictive performance	-	0	0	0	0	+	+	0	0	0	-	0	+	+
xi) evidence consistency	-	0	0	-	-	+	+	+	-	0	-	-	0	+
xii) evidence coherence		Not enough data	Not enough data							Very little siltation downstream				
<b>Total</b>	<b>-6</b>	<b>+1</b>	<b>+1</b>	<b>0</b>	<b>-5</b>	<b>+6</b>	<b>+6</b>	<b>+6</b>	<b>-5</b>	<b>+4</b>	<b>-2</b>	<b>-5</b>	<b>+5</b>	<b>+6</b>

+ = evidence supports; 0 = no evidence to support or refute; - = evidence does not support

Evidence categories ii, vi, and ix are rated as 0 for all possible causes. Evidence of temporality was unavailable due to a lack of biological samples over time. Evidence from experiments was unavailable due to a lack of experiments associated with the impairment. Evidence regarding specificity of cause was unavailable due to the general nature of the biological impairment.

2. *Eliminate alternatives*

Based on the strength of evidence chart above, we are eliminating TSS/turbidity, toxins, chloride, ammonia, pH, thermal modification, silt/sediment, channelization, and loss of riparian vegetation.

**F. Identify Probable Cause and Evaluate Confidence**

1. *Describe the cause in as much detail as possible*
2. *Summarize the basis for the determination*
3. *Present any uncertainties*
4. *Determine confidence level*

**Nutrients (N and P)**

Excess nutrients, both nitrogen and phosphorus, in Milford Creek have led to reduced BMIBI scores. Elevated nutrient levels in the stream, both phosphorus and nitrogen, contribute to algae and aquatic macrophyte growth. Undesirable filamentous algal growth reduces the availability and suitability of rock and wood substrates favored by sensitive benthic macroinvertebrate taxa. Algae and macrophyte growth can also cause pronounced daily swings in dissolved oxygen and nightly dissolved oxygen sags. In Milford Creek, these overnight sags send dissolved oxygen levels below the 4 mg/l standard for Class B(LR) streams (IAC, 2004) regularly during low flow periods and often below 2 mg/l. These levels of oxygen could cause stress or even suffocation in the invertebrate community.

Nutrient levels were identified as a problem in the Milford Creek watershed based largely on samples collected by UHL (Appendix II). Although nitrate concentrations did not rise above 8.4 mg/l, total Kjeldahl nitrogen was generally at or above 1 mg/l with event samples reaching 4.8 and non-event samples up to 3.0. Total phosphorus concentrations at the upstream site were generally at or below 0.1 mg/l with a high concentration of 0.85 mg/l. At the downstream site, both during the regular monthly samples and during events, total phosphorus concentrations were regularly greater than 1.0 mg/l.

In general, nitrate and total phosphorus levels were low at the upstream site and high at the downstream site. This is probably due to the fact that the Iowa Great Lakes Sanitary District discharges between the two sites. Another factor that may influence this is nutrient uptake by aquatic plants and algae at the upstream site, which is marsh-like.

We believe that the data are sufficient to conclude that high nutrient levels in Milford Creek contribute significantly to the impairment of the biological community. We believe there is strong enough evidence to justify action to reduce phosphorus and/or nitrogen levels in Milford Creek, and that this action will have a positive impact on the aquatic community.

### **Dissolved Oxygen**

Low levels of and extreme fluctuations in dissolved oxygen have led to reduced BMIBI scores. Iowa water quality standards state that the minimum level of dissolved oxygen is 4.0 mg/l and that levels must be at least 5.0 for 16 hours of every 24-hour period. These standards were designed to allow the support of aquatic life. The low levels of dissolved oxygen found in Milford Creek could cause stress or suffocation in the invertebrate community.

Dissolved oxygen measurements taken over a two-week period by an autosampler show that oxygen levels fluctuate widely over each 24-hour period with dissolved oxygen dipping below 2 mg/l each night for four to twelve hours at a time. Monthly grab samples collected by UHL show low levels of dissolved oxygen on several occasions. Levels were below 5.0 mg/l on three occasions and at or below 6.0 mg/l on nine occasions. Although these samples do not all reflect violations, the time of sample collection must be considered. In most cases, the dissolved oxygen measurements were made in the morning. At this time of day, the sun has been up for short time, allowing photosynthetic activity to replenish a portion of the oxygen supply. Therefore, these low values may indicate a dissolved oxygen flux such as that monitored in Milford Creek from 8/17/04 to 9/1/2004 (Figure 8).

At the upstream site, dissolved oxygen levels may cause the habitat to be even less hospitable. Samples collected on 8/14/01 and 6/11/02 were collected at 1:15 PM and 12:30 PM but had dissolved oxygen levels of 5.2 and 4.4 mg/l, respectively. At this time of the day, dissolved oxygen should be reaching its peak. During the 2001 sample, there was no detectable flow and nitrate levels were below the detection limit. Plant and algal growth may have been nitrate limited and so oxygen was not being produced through photosynthesis. During the 2002 sample, flow was 56 cfs and nitrate and phosphorus levels were low, but detectable.

We are very confident that low levels of dissolved oxygen are causing reductions in the biological community. The large fluctuations in oxygen levels shown in Figure 8 have been documented in other Iowa streams and are considered a common phenomenon in streams under low flow conditions with nutrient loads that promote primary production.

### **Macrophytes and Algal Growth**

Excessive macrophyte and algae growth have led to a reduction in the BMIBI scores in Milford Creek. Macrophytes and algae can cause pronounced daily swings in dissolved oxygen, including nightly dissolved oxygen sags. In Milford Creek, these sags send dissolved oxygen levels below the 5 mg/l standard regularly during low flow periods and often below 2 mg/l. In addition, algal growth covers hard substrate and limits the availability of habitat for benthic macroinvertebrates. This is especially true of scraper organisms, which are replaced by collector filterers and gatherers in organically enriched conditions.

The relatively high level of chlorophyll in Milford Creek indicates plant and algal growth in Milford Creek. Chlorophyll a concentrations (corrected for pheophytin) were 72 mg/l in the water, 130 mg/l in the periphyton, and 38 mg/l in the sediment. Corrected chlorophyll levels measured on September 14, 2004 following a storm event were lower, suggesting the algal biomass fluctuates with changing flow and weather conditions. Visual observations of Milford Creek on August 4 (Figure 4) and July 1, 2004 (Figure 5) also suggest excessive algal growth in the stream. In addition, the photosynthetic activity and respiration of these organisms is evident in the extreme fluctuations of dissolved oxygen levels.

We are confident that excessive macrophytes and algal growth are a contributing factor in the reduced BMIBI scores found at Milford Creek. Direct physical observation, measured data, and predictive parameters all support this conclusion.

Figure 4. Photograph from Milford Creek on August 4, 2004.



Figure 5. Photographs of Milford Creek on July 1, 2004.



### **Flow Alteration**

Anthropogenic changes in the flow of Milford Creek have led to a reduction in the BMIBI scores. Flow in Milford Creek has been altered in three ways: 1) the addition of the dam at the outlet of Lower Gar Lake; 2) the creation of a diurnally-fluctuating artificial baseflow by the wastewater treatment plant; and 3) the channelization of flow through culverts where roads cross the stream.

The dam at Lower Gar limits the flow regime at the upstream site. Instead of having a relatively steady, low flow for a large portion of the year, the upper reaches of Milford Creek have high flows for a portion of the spring and no detectable flow for most of the rest of the year. The habitat summary for the upstream site (site 50) in Table 3 shows the percent riffle, run, and pool as 0, 0, and 100, respectively. The structure at the outlet of Lower Gar Lake prevents flow from entering Milford Creek during dry periods. This creates a stagnant condition that is not suitable for supporting a stream benthic macroinvertebrate assemblage.

The Iowa Great Lakes Sanitary District STP is a continuous discharge facility with a maximum daily permitted effluent flow of 7.72 million gallons per day (mgd) and a maximum 30-day average flow of 5.03 mgd. A comparison of discharge flow from the wastewater treatment plant with the flow data collected by UHL may be found in Tables 3 and 4. These tables show that a significant portion of the flow in Milford Creek comes from the Iowa Great Lakes Sanitary District STP, even during storm events.

Continuous flow data collected during summer 2004 at the downstream site show a consistent diurnal flow pattern that is probably caused by variations in wastewater discharge from the Iowa Great Lakes Sanitary facility (Figure 11). Late night-early morning flow levels in Milford Creek were less than half of the midday flow levels. This flow fluctuation is potentially stressful to the aquatic community of Milford Creek. It also is likely a confounding factor that contributes to overnight dissolved oxygen sags.

Table 3. Monthly average flow from the Iowa Great Lakes Sanitary District STP compared with single-day grab sample measurements at the downstream site (site 49).

Month	30 Day Avg (mgd)	30 Day Avg (cfs)	Date	Stream Flow (cfs)
3/2001	2.1700	3.35699	3/13/2001	3.5
4/2001	4.2600	6.59022	4/10/2001	7.2
5/2001	4.2000	6.4974	5/8/2001	184
6/2001	4.1400	6.40458	6/12/2001	110
7/2001	3.4100	5.27527	7/17/2001	92
8/2001	2.7600	4.26972	8/14/2001	5.4
9/2001	2.2000	3.4034	9/5/2001	4.9
10/2001	1.9000	2.9393	10/9/2001	9.9
11/2001	1.8400	2.84648	11/13/2001	5.6

Table 4. Daily flow from the Iowa Great Lakes Sanitary District STP compared with grab sample measurements at the downstream site (site 49) on the same day.

Date	Daily Maximum (mgd)	Daily Maximum (cfs)	Stream Flow (cfs)
6/07/2004	2.6730	4.14	5.7
7/06/2004	4.0000	6.19	11.4 *
7/12/2004	3.7000	5.72	10.6 *
7/21/2004	3.2000	4.95	11.6 *

\* = event sample

The use of culverts at roadway crossings restricts the natural flow of Milford Creek, particularly during storm events and other high-flow periods. This restriction of flow causes scouring of the streambed during storm events. Scouring removes benthic macroinvertebrates from their habitat.

There is some uncertainty in this parameter. There are no direct measurements available to quantify the amount of flow alteration caused by the culverts. In addition, there are no readily available data to evaluate how the outlet structure from Lower Gar Lake alters the natural stream flow regime.

We are confident that alterations to flow are adversely affecting the biological assemblage in Milford Creek. The daily flow fluctuation associated with the wastewater discharge should be investigated further to determine its role in the dissolved oxygen dynamics.

## G. Make a Decision / Recommend an Action

### 1. Causes are identified

Milford Creek is primarily impaired by degraded water quality and secondarily by habitat alterations. The main water quality problem is nutrient enrichment which is allowing excessive growth of plants and algae which are depleting dissolved oxygen supplies at night. Flow alteration and silt/sediment deposition also contribute to the biological impairment. Siltation is primarily a problem in upstream reaches where stream flow is sluggish.

For the purposes of TMDL development, the main causes of impairment are low dissolved oxygen and excess aquatic plant and algal growth caused by excess nutrients and high BOD.

### 2. Recommend actions

#### Nutrients (N and P)

It is important that the Iowa Great Lakes Sanitary District work to reduce nutrient inputs into Milford Creek. As the primary provider of flow to Milford Creek for most of the summer and fall, the concentration of nutrients leaving the plant will be closely related to the concentration of nutrients in the creek. Because the growth of plants

and algae require both nitrogen and phosphorus, we recommend that an analysis of nutrient loading from the watershed and wastewater discharge be conducted to determine what reductions are needed to prevent excessive growth of algae and aquatic macrophytes.

#### Dissolved Oxygen

The relative contributions of instream primary production and community respiration versus oxygen-demanding substances from the wastewater discharge are currently not known. Modeling should be done to quantify the contributions of the sources of oxygen demand in the watershed and within the stream itself.

#### Macrophytes and Algal Growth

Modeling of nutrient loading and of the growth responses of algae and macrophytes to these loads is needed to determine the levels of nutrient reduction needed to prevent excessive growth and oxygen fluctuation.

#### Flow Alteration

The use of a water retention structure at the wastewater treatment plant to reduce the magnitude of the daily fluctuations in flow would help restore a less-artificial flow regime. The addition of a V-notch weir or other structure to the dam from Lower Gar Lake might return a more natural baseflow to Milford Creek above the wastewater treatment plant. Future road construction projects that include a route over Milford Creek should consider the use of bridges instead of a series of culverts.

#### Silt/Sediment

A reduction in bed/bank, sheet/rill, and gully erosion should decrease the siltation and sedimentation of the streambed.

## **References**

IAC. 2004. Chapter 567-61: water quality standards. Iowa Administrative Code [effective date 6/16/04].

IDNR. 2004. Draft Protocol for Stressor Identification. Iowa Department of Natural Resources. September 2004.

US EPA. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency. December 2000.

## Appendix I

### Summary of data provided by DNR Biological Assessments.

Samples were collected at two locations along Milford Creek by members of the TMDL and Water Quality Assessment Section of the DNR. A map of these locations is available in Figure 6. The two sites were sampled in September 2001.

Biological samples of both fish and benthic macroinvertebrates were collected and analyzed. Additional parameters that were sampled are:

- Flow
- Streambank Status
- Stream Habitat
- Riparian Zone Properties
- Streambed Composition

A summary of the physical and biological parameters may be found in Table 6.

Figure 6. Locations and identification codes for biological sampling sites.

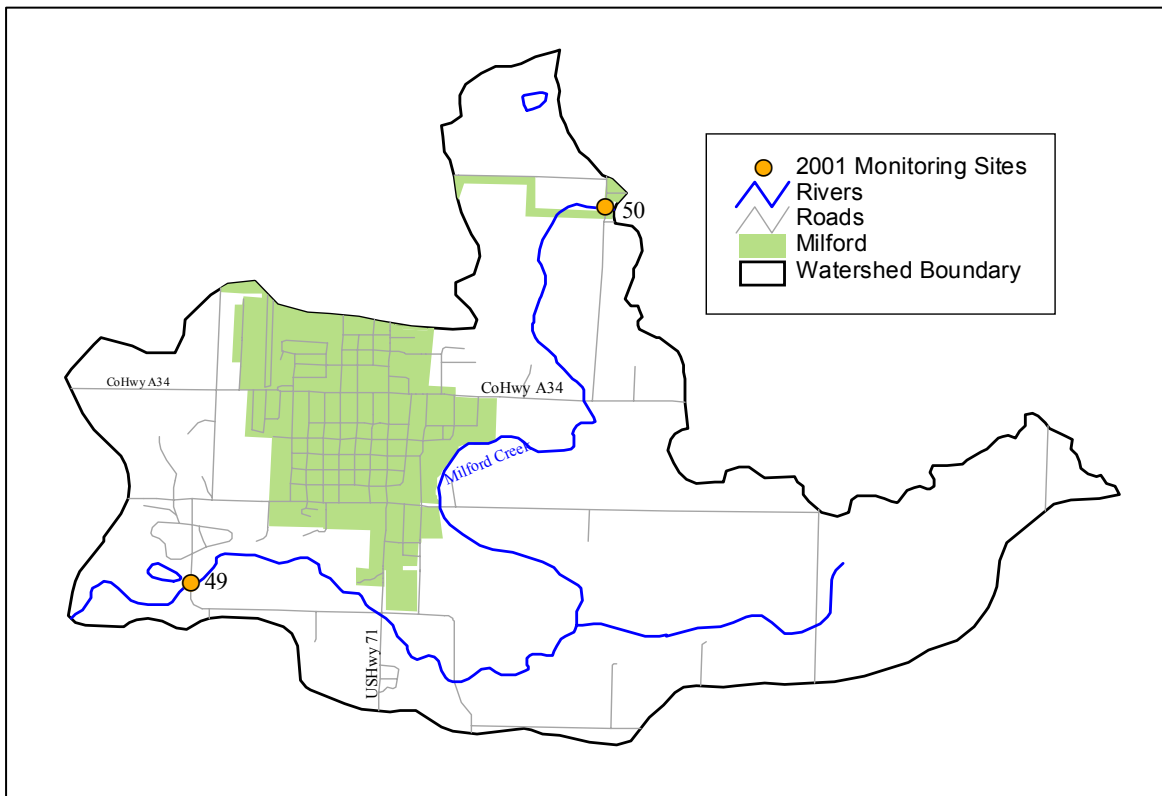


Table 6. Biological community composition at the two Milford Creek sites.

	Site 49 9/6/01	Site 50 9/6/01
<b>Fish</b>		
Black Bullhead	82	310
Channel Catfish	1	
Stonecat	49	
Yellow Bullhead	89	15
Freshwater Drum		3
Bluntnose Minnow	28	
Common Carp	15	3
Creek Chub	12	5
Unknown Cyprinids	1	
Northern Pike	1	7
Iowa Darter	5	
Johnny Darter	10	
Walleye		11
Yellow Perch	1	15
Quillback Carpsucker		1
White Sucker	6	53
Black Crappie	1	15
Bluegill	209	44
Crappie spp.		5
Green Sunfish	6	3
Largemouth Bass	16	13
Pumpkinseed		1
White Crappie		1
Total Fish	532	505
<b>Benthic Macroinvertebrates</b>		
Amphipoda	4	30
Basommatophora	5	17
Coleoptera	57	10
Decapoda	1	
Diptera (Chironomidae)	118 (115)	308 (308)
Ephemeroptera	137	40
Hemiptera	7	1
Odonata	15	27
Pharyngobdellida	3	6
Rhynchobdellida	1	
Trichoptera	147	14
Tricladida	83	
Veneroida		1
Bivalvia	3	
Nematomorpha	1	2
Oligochaeta	8	
Total Invertebrates	590	456
<b>Stream Properties</b>		
Flow (cfs)	4.9	0
Max. Depth, Avg. Depth (ft)	3.6, 0.7	1.6, 0.6
Average Width (ft)	22	55
% Pool, Riffle, Run	25, 29, 46	100, 0, 0
% Gravel, Cobble, Boulder	28, 50, 2	26, 4, 4

% Fines (sand, silt, soil, clay)	20	66
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## Appendix II

### Summary of data provided by University Hygienic Laboratory.

Samples were collected at two locations along Milford Creek by the University Hygienic Laboratory (UHL) under contract with the DNR. A map of the locations is available in Figure 7.

Parameters that were sampled on a monthly basis in 2001 and periodically in 2004 are:

- |                     |                         |                                |             |
|---------------------|-------------------------|--------------------------------|-------------|
| • Ammonia           | • Orthophosphate        | • Specific Conductance         | • Flow Rate |
| • Nitrate/Nitrite   | • Phosphorus            | • Total Suspended Solids (TSS) | • pH        |
| • Kjeldahl Nitrogen | • Dissolved Oxygen (DO) | • Temperature                  | • CBOD      |

All of the data for the parameters listed above are shown in Table 7. Highlighted values are violations of state water quality standards. Ammonia violations are of the chronic standard, not the acute standard.

The diagrams shown in Figures 8 and 9 show load duration curves for TSS, nitrate and phosphorus in Milford Creek. An auto sampler was deployed at site 49 in 2004 to measure variations in DO and Temperature. Graphs of these changes over time may be found in Figure 10.

Figure 7. Locations and identification codes for UHL sampling sites.

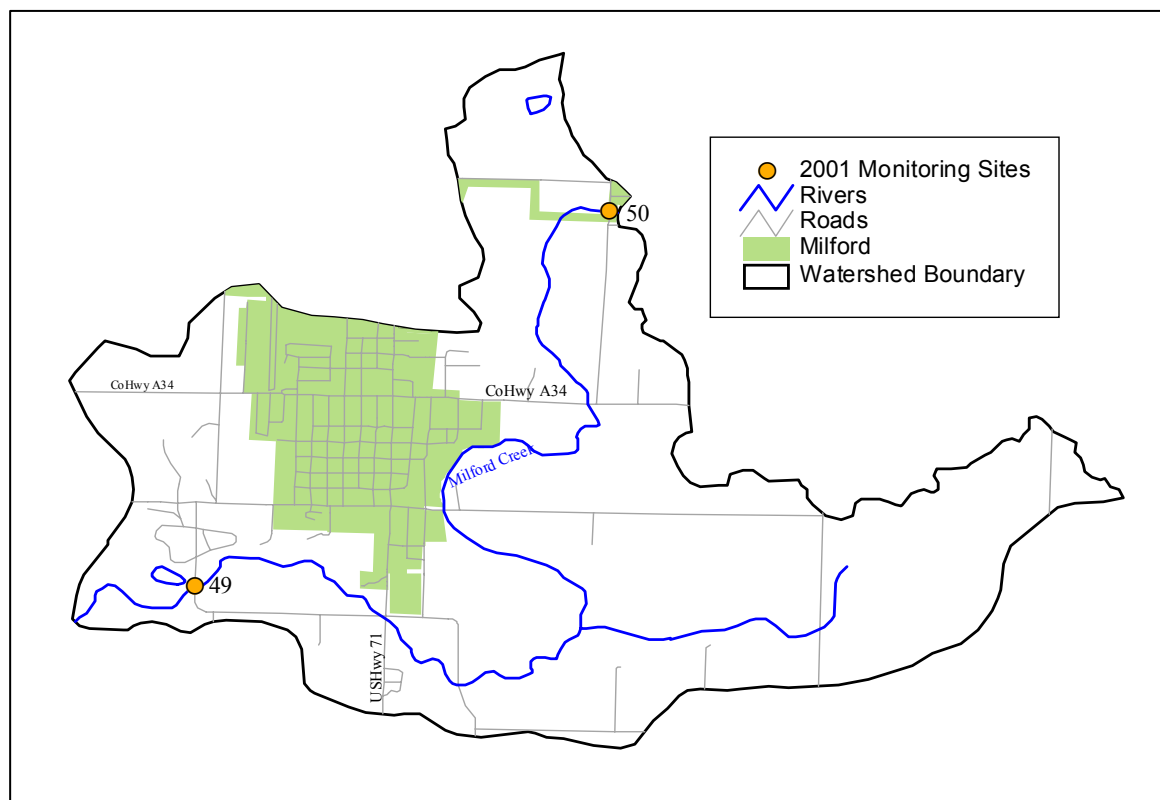


Table 7. Data collected by UHL for the DNR in 2001, 2002, and 2004.

Collection Date	Sample Time	CBOD (5-d) (mg/l)	CBOD (20-d) (mg/l)	DO (mg/l)	pH	Temp (deg C)	NH3 as N (mg/l)	NO3 + NO2 as N (mg/l)	TKN as N (mg/l)	Flow Rate (cfs)
<b>Event Sampling - Site 49 (Southwest of Milford)</b>										
3/13/2001	13:15	<2		7.5	8.1	3.6	0.7	7.9	2.1	8.6
3/27/2001	13:45	<2		11.4	7.9	0.8	0.7	6.3	1.9	9
5/29/2004 (pre)			18				0.26	1.8	2	
5/29/2004 (post)			19				0.08	3.9	2.9	
5/29/2004 (grab)	22:00			14	9	22.8				14
7/6/2004 (c)			14				4.5	2	4.8	
7/6/2004 (grab)	18:15			19.5	8.3	12.4				11.4
7/12/2004 (c)			15				0.16	2.1	3	
7/12/2004 (grab)	7:10			11.8	8.6	30.4				10.6
7/21/2004 (c)			18				0.29	2	1.8	
7/21/2004 (grab)	13:30			15.7	8.2	30				11.6
8/4/2004 (pre)			40				0.31	2	2.8	
8/4/2004 (post)			21				1.1	2.4	2.7	
8/4/2004 (grab)	8:15			3.9	7.7	20.7				14.1
<b>Monthly Sampling - Site 49 (Southwest of Milford)</b>										
3/13/2001		<2		10.7	8.5	0.7	0.4	8.4	1.2	3.5
4/10/2001	8:00	<2		10.4	8.9	10.1	<0.1	6	1.2	7.2
5/8/2001	9:10	2		8.8	8.5	13.3	<0.1	1.4	0.3	184
6/12/2001	9:00	<2		6.6	8.2	22.2	0.2	0.9	0.9	110
7/17/2001	9:30	2		5.9	7.9	25.5	<0.1	0.8	1.3	92
8/14/2001	14:00	3		10.5	8.5	21.4	<0.1	4.3	1.6	5.4
9/5/2001		2		5.7	8	19.5	0.28	8.1	1.9	4.9
10/9/2001		2		8.8	8.2	12.4	<0.05	5.1	1.3	9.9
11/13/2001	11:15	<2		12.5	8.5	11.2	<0.05	4.5	0.68	5.6
6/7/2004	14:40		8	17.5	9.3	29.5	<0.05	3	1.6	5.7
7/12/2004	15:30		17	11.8	8.6	30.4	0.74	1.6	2.1	10.6
8/10/2004	8:00		15	4.2	7.9	17	0.06	2.4	1.3	7.9
8/17/2004	15:00		17	13.2	8.7	26.1	0.07	1.7	1.7	6.9
<b>Monthly Sampling - Site 50 (Northeast of Milford)</b>										
4/10/2001	7:30	5		11.1	8.2	9.8	0.5	0.2	1.9	
5/8/2001	8:15	<2		9.3	8.7	14	<0.1	0.7	0.8	167
6/12/2001	7:45	<2		6	7.9	23.6	0.1	0.4	1	110
7/17/2001	8:00	<2		6	8.2	26	<0.1	0.1	1	83
8/14/2001	13:15	5		5.2	8	21.7	0.6	<0.1	3	0
9/5/2001		9		8.4	7.6	21.9	0.51	<0.1	2.7	0
10/9/2001		3		5.8	8	13	<0.05	0.3	1.9	0
11/13/2001	12:00	<2		7.6	8	12.3	<0.05	0.6	1.2	0
5/8/2002	13:15			10	8.2	15	<0.1	<0.1	2.3	0
6/11/2002	12:30			4.4	7.9	22	0.3	0.2	1.3	56

For event samples, pre=pre-peak sample; post=post-peak sample;  
grab=post-event grab sample; c=composite event sample.

Table 7 (continued).

Collection Date	Specific Conductance (umhos/cm)	Filterable Ortho. as P (mg/l)	Total Phosphate as P (mg/l)	TSS (mg/l)	TVSS (mg/l)	Turbidity (NTU)	Silica (mg/l)	Total Alkalinity (mg/l)
<b>Event Sampling - Site 49 (Southwest of Milford)</b>								
3/13/2001	780	1.4	1.4	6				
3/27/2001	850	0.9	1.2	11				
5/29/2004 (pre)	570	0.71	1.1	140	24			
5/29/2004 (post)	770	0.76	1.1	12	6			
5/29/2004 (grab)						3.9		
7/6/2004 (c)	720	2.2	2.4	27	8			
7/6/2004 (grab)								
7/12/2004 (c)	600	1.3	1.7	170	25			
7/12/2004 (grab)								
7/21/2004 (c)	610	1.5	1.7	39	8			
7/21/2004 (grab)								
8/4/2004 (pre)	700	1.7	2.4	130	24			
8/4/2004 (post)	750	2.3	2.4	25	5			
8/4/2004 (grab)								
<b>Monthly Sampling - Site 49 (Southwest of Milford)</b>								
3/13/2001	880	1.9	2	5				
4/10/2001	800	0.6	0.7	11				
5/8/2001	490	0.1	0.2	37				
6/12/2001	500	0.13	0.1	27				
7/17/2001	490	0.22	0.3	36				
8/14/2001	740	0.72	0.41	8				
9/5/2001	940	2	2.2	7				
10/9/2001	880	2.2	2.1	17				
11/13/2001	820	1.3	1.1	4				
6/7/2004	800	0.34	0.58	9	2			
7/12/2004	570	1.5	1.6	7	2			
8/10/2004	960	3.1	3	4	1			
8/17/2004	930	1.8	2	12	6	5	3.6	
<b>Monthly Sampling - Site 50 (Northeast of Milford)</b>								
4/10/2001	490	<0.1	<0.1	7				
5/8/2001	450	<0.02	0.1	6				
6/12/2001	460	0.06	<0.1	19				
7/17/2001	450	0.02	<0.1	12				
8/14/2001	480	0.03	0.85	24				
9/5/2001	510	<0.02	0.03	23				
10/9/2001	490	0.03	0.08	4				
11/13/2001	540	<0.05	0.08	10				
5/8/2002	590	<0.02	0.3	32	17		9.1	210
6/11/2002	590	<0.02	0.1	84	18		7.1	190

For event samples, pre=pre-peak sample; post=post-peak sample;

grab=post-event grab sample; c=composite event sample.

Table 7 (continued).

Collection Date	TDS (mg/l)	Chl a (ug/l)	Chl b (ug/l)	Chl c (ug/l)	Corrected Chl a (ug/l)	Pheophytin (ug/l)	Chloride (mg/l)	Sample Vol (ml)	Filter Vol (ml)
8/17/2004 in water	520	82	<1	7	72	11	96		
8/17/2004 in periphyton		150	15	8.9	130	32		295	25
8/17/2004 in sediment		58	8.2	4.1	38	32		240	20
9/14/2004 in water	410	17	<1	<1	11	10	61		
9/14/2004 in periphyton		15	1.9	0.5	12	3.8		114	54
9/14/2004 in sediment		20	0.8	0.8	11	15		305	50

Figure 8. Load duration curves for Milford Creek. Load estimates are based on USGS flow data at Milford Creek from 10/1/71 to 9/30/74. Loads are based on a TSS limit of 62 mg/l, a Total P limit of 0.57 mg/l, and a Nitrate N limit of 10.5 mg/l. These limits are based on the mean plus the standard deviation for the measurements at the reference sites.

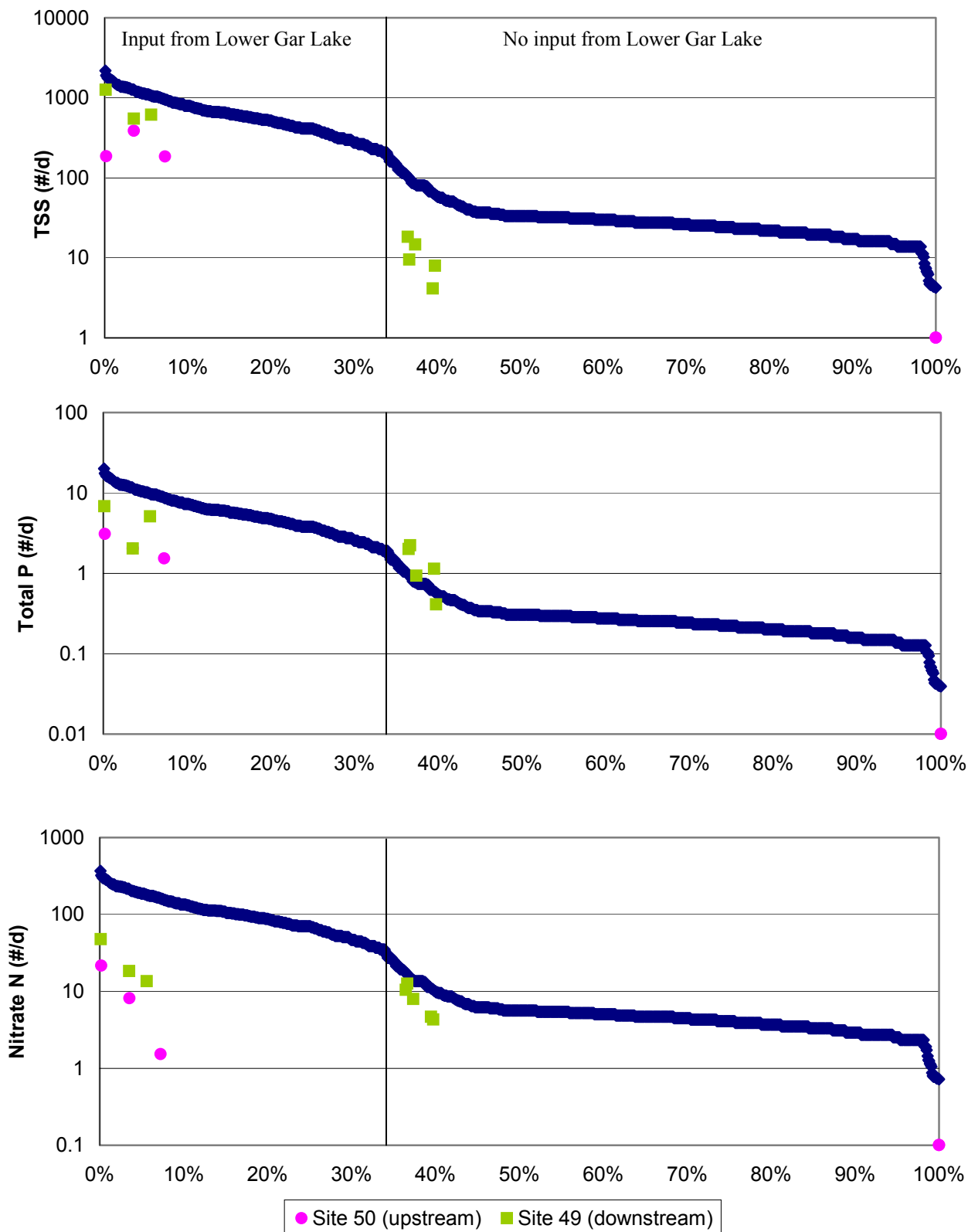


Figure 9. Load duration curves for Milford Creek. Load estimates are based on hourly ISCO flow data at Site 49 on Milford Creek from 6/28/01 to 12/10/01. Loads are based on a TSS limit of 62 mg/l, a Total P limit of 0.57 mg/l, and a Nitrate N limit of 10.5 mg/l. These limits are based on the mean plus the standard deviation for the measurements at the reference sites.

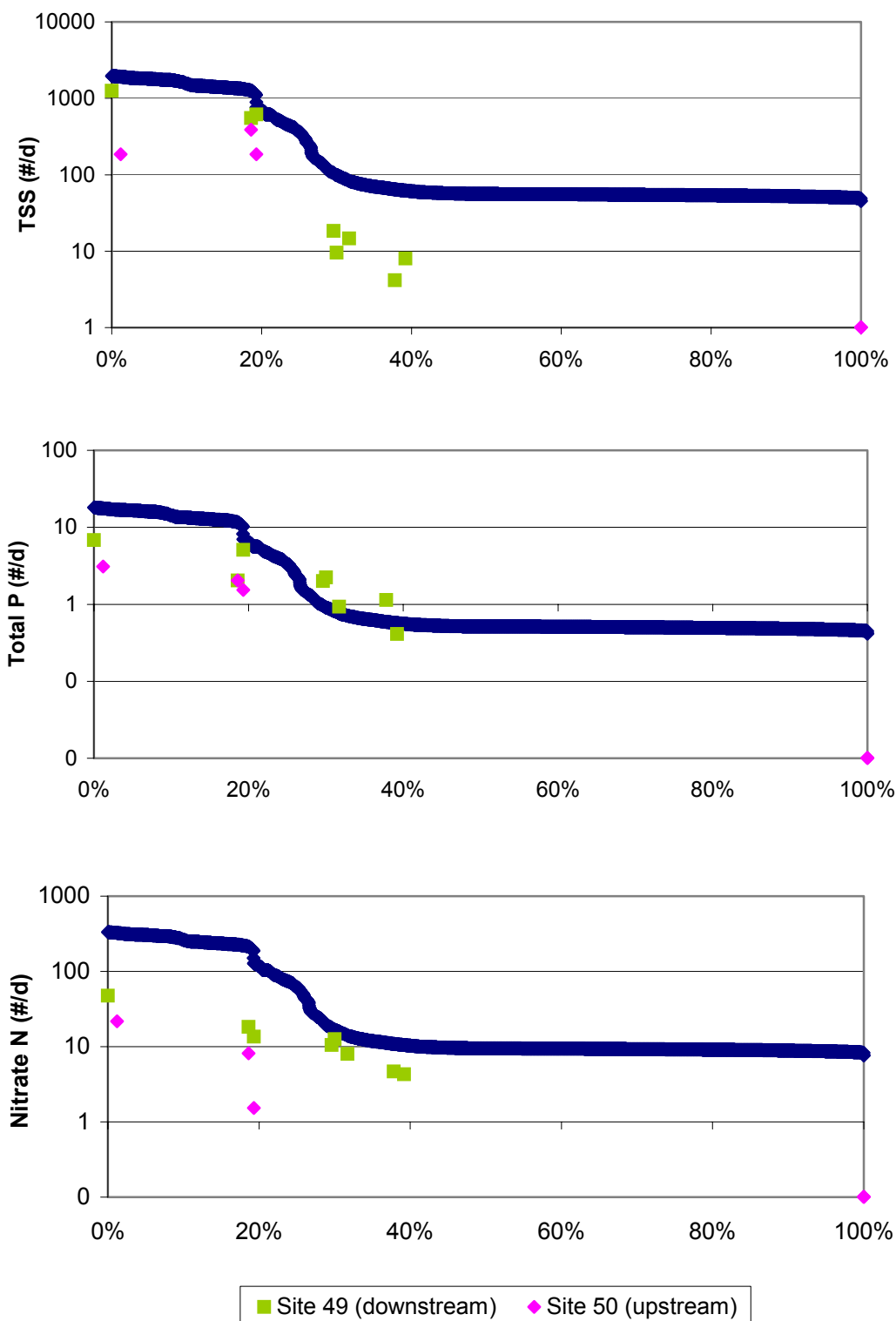


Figure 10. Dissolved oxygen and temperature measurements collected by an auto sampler in Milford Creek.

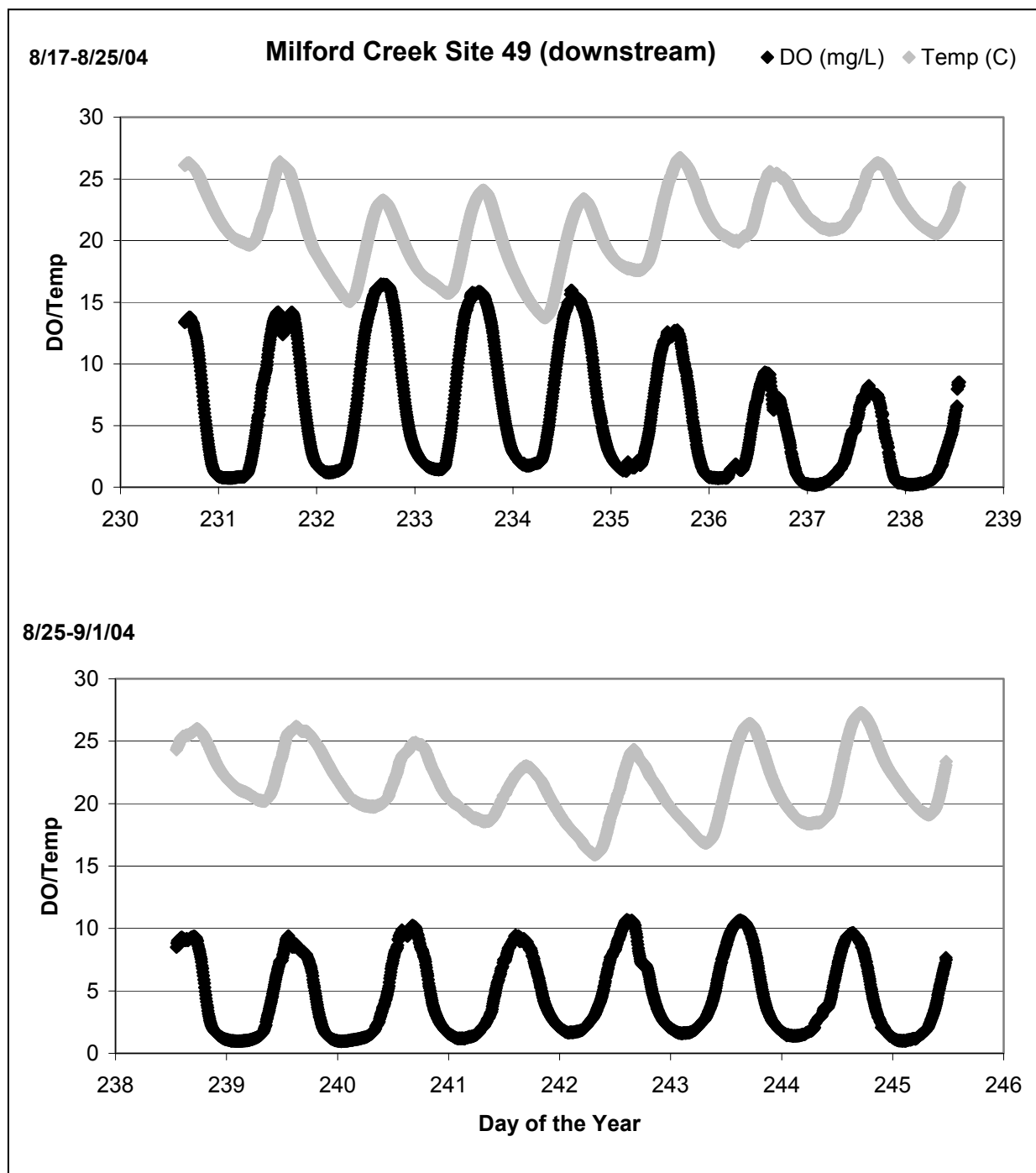
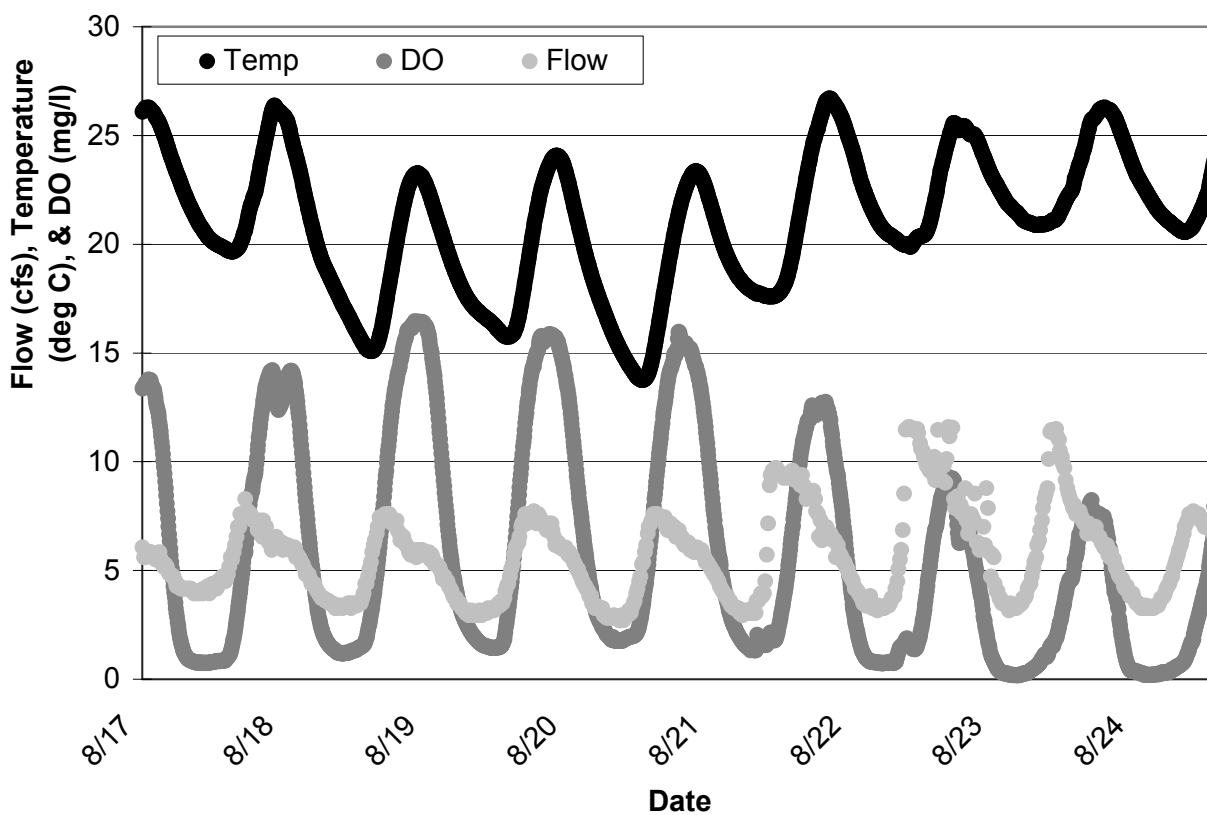


Figure 11. Daily variations in flow, dissolved oxygen, and temperature from August 17 to August 25, 2004.



### Appendix III

#### Summary of data from the Iowa Great Lakes Sanitary District STP.

Samples of treated effluent are collected regularly for water quality analysis. Table 8 provides information about effluent flow rates.

Parameters that are reported on a monthly basis are:

- Ammonia
- CBOD5
- Flow Rate
- Toxicity
- Total Suspended Solids (TSS)
- pH

Table 8. Monthly flow measurements from the Iowa Great Lakes Sanitary District since 2000.

Period End Date	30D/Ave (mgd)	30D/Ave (cfs)	Maximum (mgd)	Maximum (cfs)	Period End Date	30D/Ave (mgd)	30D/Ave (cfs)	Maximum (mgd)	Maximum (cfs)
05/31/2004	2.527	3.910	4.752	7.351	02/28/2002	1.800	2.785	1.890	2.924
04/30/2004	1.945	3.009	2.514	3.889	01/31/2002	1.800	2.785	1.900	2.939
03/31/2004	1.955	3.024	2.388	3.694	12/31/2001	1.900	2.939	2.100	3.249
02/29/2004	1.599	2.474	1.977	3.058	11/30/2001	1.840	2.846	2.500	3.868
01/31/2004	1.585	2.451	1.738	2.689	10/31/2001	1.900	2.939	2.190	3.388
12/31/2003	1.665	2.576	1.907	2.950	09/30/2001	2.200	3.403	3.100	4.796
11/30/2003	1.662	2.571	1.746	2.701	08/31/2001	2.760	4.270	3.460	5.353
10/31/2003	1.770	2.738	2.280	3.527	07/31/2001	3.410	5.275	4.340	6.714
09/30/2003	2.056	3.181	2.997	4.636	06/30/2001	4.140	6.405	7.070	10.937
08/31/2003	2.562	3.963	3.007	4.652	05/31/2001	4.200	6.497	5.860	9.065
07/31/2003	3.091	4.782	4.276	6.615	04/30/2001	4.260	6.590	7.680	11.881
06/30/2003	3.030	4.687	3.417	5.286	03/31/2001	2.170	3.357	3.330	5.152
05/31/2003	2.751	4.256	3.420	5.291	02/28/2001	1.880	2.908	2.030	3.140
04/30/2003	2.203	3.408	2.551	3.946	01/31/2001	1.750	2.707	1.930	2.986
03/31/2003	1.875	2.901	2.607	4.033	12/31/2000	1.760	2.723	1.900	2.939
02/28/2003	1.753	2.712	1.910	2.955	11/30/2000	1.960	3.032	2.670	4.130
01/31/2003	1.750	2.707	1.930	2.986	10/31/2000	1.820	2.816	2.100	3.249
12/31/2002	1.824	2.822	1.889	2.922	09/30/2000	2.500	3.868	3.030	4.687
11/30/2002	1.900	2.939	2.000	3.094	08/31/2000	2.500	3.868	3.030	4.687
10/31/2002	2.200	3.403	2.600	4.022	07/31/2000	2.990	4.626	3.770	5.832
09/30/2002	2.300	3.558	3.400	5.260	06/30/2000	2.830	4.378	3.290	5.090
08/31/2002	3.000	4.641	4.400	6.807	05/31/2000	2.490	3.852	3.820	5.910
07/31/2002	2.800	4.332	3.800	5.879	4/30/2000	2.040	3.156	2.200	3.403
06/30/2002	3.000	4.641	4.700	7.271	3/31/2000	1.890	2.924	2.040	3.156
05/31/2002	2.500	3.868	3.100	4.796	2/29/2000	1.880	2.908	2.030	3.140
04/30/2002	2.100	3.249	2.800	4.332	1/31/2000	1.870	2.893	1.970	3.048
03/31/2002	1.890	2.924	2.160	3.342					